Unit Descriptors for the Pearson BTEC Higher Nationals Engineering Suite (2024)

Issue 6 (N.B. to be delivered from **1st September 2024**).

For use with:

Pearson BTEC Higher Nationals in Aeronautical Engineering (2024)

Pearson BTEC Higher Nationals in Aeronautical Engineering for England (2024)

Pearson BTEC Higher Nationals in Automation and Control Engineering for England (2024)

Pearson BTEC Higher Nationals in Automotive Engineering (2024)

Pearson BTEC Higher Nationals in Computer Systems Engineering for England (2024)

Pearson BTEC Higher Nationals in Electrical and Electronic Engineering for England (2024)

Pearson BTEC Higher Nationals in Electronic Systems Engineering for England (2024)

Pearson BTEC Higher Nationals in Electrical Systems Engineering for England (2024)

Pearson BTEC Higher Nationals in Electronic and Electrical Systems Engineering for England (2024)

Pearson BTEC Higher Nationals in Engineering (2024)

Pearson BTEC Higher Nationals in Engineering for England (2024)

Pearson BTEC Higher Nationals in Manufacturing Engineering for England (2024)

Pearson BTEC Higher Nationals in Manufacturing Operations for England (2024)

Pearson BTEC Higher Nationals in Mechanical Engineering for England (2024)

Pearson BTEC Higher Nationals in Mechatronics for England (2024)

Pearson BTEC Higher Nationals in Operations Engineering for England (2024)

Pearson BTEC Higher Nationals in Space Technologies for England (2024)

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All information in this specification is correct at time of publication.

Summary of Unit Descriptors for the Pearson BTEC Higher Nationals Engineering Suite Issue 5 changes

Summary of changes made between previous issue and this current issue	Page number
4.0 Unit 5013 Embedded Systems Corrected typo - Criteria number	936
4.0 Unit 5023 Thermofluids Corrected typo - Unit credits	1004

Summary of Unit Descriptors for the Pearson BTEC Higher Nationals Engineering Suite Issue 5 changes

Summary of changes made between Issue 4 and Issue 5	Page number
4.0 Unit 4002 Engineering Mathematics P5 Inserted missing “,”	21
4.0 Unit 4009 Materials, Properties and Testing Corrected typos – criteria numbers	76
4.0 Unit 4013 Fundamentals of Thermodynamics and Heat Transfer Corrected typos – M2 and D2	103
4.0 Unit 4016 Instrumentation and Control Systems Corrected typos – criteria numbers	126
4.0 Unit 4088 Space Technologies and Manufacturing Reinstated missing M4 assessment criteria	682
4.0 Unit 5041 Engineering Project Corrected typos – criteria numbers	1158 – 1159
4.0 Unit 5023 Thermofluids Removed typo M1	1158 – 1159

Summary of Unit Descriptors for the Pearson BTEC Higher Nationals Engineering Suite Issue 4 changes

Summary of changes made between Issue 3 and this Issue 4	Page numbers
Front cover Added new Higher Nationals in Automotive Engineering (2024) to the list of qualifications	
4.0 Unit Descriptors Added new units: Unit 4091: Automotive Fundamentals Unit 4092: Vehicle Dynamics and Performance	1147-1406

Unit 4093: Race Car Design and Manufacturing Unit 4094 Motorsport Workshop Practices Unit 4095: Automotive Combustion Unit 4096: Automotive Workshop Practices Unit 4097: Electric Vehicle Battery Manufacture Unit 4098: Hybrid and Electric Vehicle Technologies Unit 4099: Industrial Digitalisation Technologies for Engineers Unit 4100: Lean Six Sigma for Engineers (leading to Green Belt) Unit 4111: Powertrain and Hybrid Vehicles Unit 4112: Vehicle Repair and Diagnostics Unit 4113: Heavy Vehicles I Unit 4114: Motorcycle Engineering Unit 4115: Vehicle Electrical and Electronics Unit 5058: Automotive Structures and Materials Unit 5059: Automotive Aerodynamics Unit 5060: Motorsport Workshop Preparation and Inspection Unit 5061: Automotive Incident Investigation Unit 5062: Engine and Vehicle Design Performance Unit 5063: Further Hybrid and Electric Vehicle Technologies Unit 5064: Further Industrial Digitalisation Technologies for Engineers Unit 5065: Hydrogen in Automotive Engineering Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt) Unit 5067: Vehicle Operations Unit 5068: Vehicle Parts Management Unit 5069: Vehicle Systems and Technology Unit 5070: Further Motorcycle Engineering Unit 5071: Heavy Vehicles II	

Summary of changes made between Issue 2 and Issue 3	**Page numbers**
Cover page List of qualifications updated in Issue 3. **All sections** Typographical errors corrected.	
Contents page Includes new units and revised unit titles as listed below: *New units:* 4032: Introduction to Biomedical Engineering 4090: Engineering Science II 5055: Aerospace Propulsion Principles and Technology 5056: Conceptual Aircraft Design 5057: Medical Instrumentation *Units with revised titles:* 4002 Engineering Mathematics *[Previous tile: Engineering Maths]* 4003 Engineering Science I *[Previous Title: Engineering Science]* 4013 Fundamentals of Thermodynamics and Heat Transfer *[Previous tile: Fundamentals of Thermodynamics and Heat Engines]* 4027: CAD for Schematics in Maintenance Engineering *[Previous Title: CAD for Maintenance Engineers]* 5004 Computational Modelling in Virtual Engineering *[Previous Title: Virtual Engineering]* 5006 Further Engineering Mathematics *[Previous Title: Further Mathematics]* 5017 Advanced Manufacturing *[Previous Title: Advanced Manufacturing Technology]*	 241-249 693-699 1128-1137 1138-1145 1146-1154

Individual units **Level 4 units – scope of revisions:** Following units are revised to address feedback received from various stakeholders (i.e., academic and employer experts, panels and focus groups, professional bodies, and students) and to meet some requirements of specific occupational standards. Please note some limited/ significant changes in all key sections namely - LOs, Essential Content, Assessment Criteria and Recommended Resources.	
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4034: Computer Aided Design (CAD) for Engineering	258-267
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Individual units **Level 5 units – scope of revisions:** Following units are revised to address feedback received from various stakeholders (i.e., academic and employer experts, panels and focus groups, professional bodies, and students) and to meet some requirements of specific occupational standards. Please note some limited/ significant changes in all key sections namely - LOs, Essential Content, Assessment Criteria and Recommended Resources.	
5001: Research Project	700-707
5002: Professional Engineering Management	708-716
5003: Advanced Mechanical Principles	717-723

5024: Emerging Semiconductor Technologies 5025: Semiconductor Integrated Electronics 5042: Signals or Systems 5048: Sensors and Automation 5051: Heating, Ventilation and Air Conditioning (HVAC)	871-878 879-885 1022-1028 1065-1072 1093-1099
New section **HN Global: Additional Resources** This new section on HN Global platform is aimed at provide additional guidance on unit-wise resources.	 1155

Earlier issue(s) show(s) previous changes.

If you need further information on these changes or what they mean, contact us via our website at: qualifications.pearson.com/en/support/contact-us.html.

Contents

1.0 Introduction

1.1 Qualifications overview

The unit descriptors included in this document are for use with the following Qualifications (only):

- Pearson BTEC Level 4 Higher National Certificate in Aeronautical Engineering: 610/3637/7
- Pearson BTEC Level 4 Higher National Certificate in Automotive Engineering: 610/4708/9
- Pearson BTEC Level 5 Higher National Diploma in Aeronautical Engineering: 610/3638/9
- Pearson BTEC Level 5 Higher National Diploma in Automotive Engineering: 610/4709/0
- Pearson BTEC Higher National Certificate in Aeronautical Engineering for England: 610/1249/X
- Pearson BTEC Higher National Diploma in Aeronautical Engineering for England: 610/1258/0
- Pearson BTEC Higher National Certificate in Automation and Control Engineering for England: 610/1190/3
- Pearson BTEC Higher National Certificate in Computer Systems Engineering for England: 610/1178/2
- Pearson BTEC Higher National Diploma in Computer Systems Engineering for England: 610/1181/2
- Pearson BTEC Higher National Certificate in Electrical and Electronic Engineering for England: 610/1220/8
- Pearson BTEC Higher National Diploma in Electrical and Electronic Engineering for England: 610/1222/1
- Pearson BTEC Higher National Certificate in Electrical Systems Engineering for England: 610/1188/5
- Pearson BTEC Higher National Diploma in Electronic and Electrical Systems Engineering for England: 610/1182/4
- Pearson BTEC Level 4 Higher National Certificate in Electronic Systems Engineering for England 610/1186/1
- Pearson BTEC Level 4 Higher National Certificate in Engineering: 610/3635/3
- Pearson BTEC Level 5 Higher National Diploma in Engineering: 610/3636/5
- Pearson BTEC Level 4 Higher National Certificate in Engineering for England: 610/1224/5
- Pearson BTEC Level 5 Higher National Diploma in Engineering for England: 610/1228/2
- Pearson BTEC Higher National Certificate in Manufacturing Engineering for England: 610/1229/4
- Pearson BTEC Higher National Diploma in Manufacturing Engineering for England: 610/1230/0

- Pearson BTEC Higher National Certificate in Manufacturing Operations for England: 610/1259/2
- Pearson BTEC Higher National Certificate in Mechanical Engineering for England: 610/1231/2
- Pearson BTEC Higher National Diploma in Mechanical Engineering for England: 610/1233/6
- Pearson BTEC Higher National Certificate in Mechatronics for England: 610/1260/9
- Pearson BTEC Higher National Certificate in Operations Engineering for England: 610/1234/8
- Pearson BTEC Level 5 Higher National Diploma in Operations Engineering for England: 610/1235/X
- Pearson BTEC Higher National Certificate in Space Technologies for England: 610/1218/X
- Pearson BTEC Higher National Diploma in Space Technologies for England: 610/1219/1

1.2 Qualifications indicated ‘for England’

Qualifications that are indicated as ‘for England’ are designed to align to the requirements of specific occupational standards that meet Institute for Apprenticeships and Technical Education (IfATE) current occupation criteria. Meeting the requirements of the occupational standards relates to:

- qualifications that are ‘quality marked’ as Higher Technical Qualifications (HTQs)
- the knowledge, skills and behaviours for identified occupations that are associated with relevant occupational standards.

These are the default qualifications for all centres in England.

1.3 Qualifications not indicated ‘for England’

Qualifications that are **not** indicated as ‘for England’ can be delivered by the other centres in the UK or overseas, subject to approvals from Pearson. These qualifications are not ‘quality marked’ as HTQs by IfATE.

Qualifications without equivalent HTQ titles may be delivered by centres in England, subject to approvals from Pearson.

2.0 Programme Structures

Programme structures define the unit combinations required for a given qualification. These are defined in *Section 6.0 Programme structures* within the relevant programme specification for the qualification.

3.0 The unit descriptor

The unit descriptor is how we define the individual units of study that make up a Higher National qualification. Students will complete the units included in the programme you offer at your Centre.

You can use any of the unit descriptors listed in *Section 4 Unit descriptors*. We have described each part of the unit as follows.

Unit title	A general statement of what the unit will cover.
Unit code	The Ofqual unit reference number.
Unit type	There are three unit types: • core (mandatory to all pathways) • specialist (mandatory to specific pathways) • optional (available to most pathways).
Unit level	All our Pearson BTEC Higher National units are at Levels 4 or 5.
Credit value	The credit value relates to the total qualification time (TQT) and unit learning hours (ULH). It is easy to calculate: • 1 credit = 10 ULH • 15 credits = 150 ULH. To complete a Higher National Certificate or Higher National Diploma, students must achieve all of the credits required. Refer to *Section 7.5 Calculating the final qualification grade* in the programme specification.
Introduction	Some general notes on the unit: • setting the scene • stating the purpose and aim, and • outlining the topics to be learned and skills gained through the unit.
Learning Outcomes	These clearly explain what students will be able to do after completing the unit. There are usually four Learning Outcomes for each unit.
Essential Content	This section covers the content that students can expect to study as they work towards achieving their Learning Outcomes.
Learning Outcomes and Assessment Criteria	Tutors can refer to this table when grading assignments. The table connects the unit's Learning Outcomes with the student's work. Assignments can be graded at 'Pass' (P), 'Merit' (M) and 'Distinction' (D), depending on the quality of the student's work.
Recommended Resources	This section lists the resources that students should use to support their study for the unit. It includes books, journals and online material. The programme tutor may also suggest resources, particularly for local information. It may also contain delivery requirements, e.g., specific equipment, case study material, learning resources, depending on the subject.

Table 1: Description of each part of the unit

Web resources – referencing

Some units have web resources as part of their recommended resources list. Hyperlinking to these resources directly can cause problems, as their locations and addresses may change. To avoid this problem we only link to the main page of the website and signpost students and tutors to the section where the resource can be found. Therefore we have referenced web resources as follows:

[1] A link to the main page of the website

[2] The title of the site

[3] The section of the website where the resource can be found

[4] The type of resource it is, for example:

- research
- general reference
- tutorials
- training
- e-books
- report
- wiki
- article
- datasets
- development tool
- discussion forum.

Examples

[1] www.designingbuildings.co.uk

[2] Designing Buildings Wiki

[3] Subjects

[4] (General reference)

4.0 Unit Descriptors

Unit 4001: Engineering Design

Unit Code: T/650/9628

Level: 4

Credits: 15

Introduction

The tremendous possibilities of the techniques and processes developed by engineers can only be realised by great design. Design turns an idea into a useful artefact, the problem into a solution, or something ugly and inefficient into an elegant, desirable, and cost-effective everyday object. Without a sound understanding of the design process, the engineer works in isolation without the links between theory and the needs of the end user.

The aim of this unit is to introduce students to the methodical steps that engineers use in creating functional products and processes as an individual or part of a design team; from a design brief to the work, and the stages involved in identifying and justifying a solution to a given engineering need.

Among the topics included in this unit are: Gantt charts and critical path analysis, stakeholder requirements, market analysis, design process management, technical drawing, modelling and prototyping, manufacturability, sustainability and environmental impact, reliability, safety and risk analyses, and ergonomics.

On successful completion of this unit, students will be able to prepare an engineering design specification that satisfies stakeholders' requirements, implement best practices when analysing and evaluating possible design solutions, prepare a written technical design report, and present their finalised design to a customer or audience.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Create a design specification for a given design brief that meets stakeholder's requirements, along with a proposed design solution

LO2 Analyse possible technical solutions to implement the proposed design specification

LO3 Produce a design report considering all key aspects including manufacturability (or design for manufacturing and assembly) and environmental impact

LO4 Present the design solution to an audience, including evaluation of feedback and future improvements.

Essential Content

LO1 **Create a design specification for a given design brief that meets stakeholder's requirements, along with a proposed design solution**

Planning techniques used to prepare a design specification:

Definition of client's/users' objectives, needs, and constraints

Definition of design constraints, function, specification (e.g., including sub-systems and integrated systems), and milestones

Planning the design task: Flow charts, Gantt charts, Design decision matrix, network, and critical path analysis necessary in the design process

Use of relevant technical/engineering/industry standards within the design process (e.g., BS8888).

Design process:

Process development, steps to consider from start to finish

The cycle from design to manufacture

Three- and five-stage design processes

Common tools and techniques used (e.g., Six Sigma, 8 wastes, etc.)

Use of data, relevant tools (e.g., design tools/software, data reporting tools)

Vocabulary used in engineering design.

Stage of the design process which includes:

Analysing the situation, providing problem statement, researching the problem, defining tasks and outputs, creating the design concept, and writing a specification

Suggest possible solutions, select a preferred solution, prepare working drawings, describe relevant manufacturing aspects/processes (e.g., serialised manufacturing, field level operations, and support), construct a prototype, test and evaluate the design against objectives, design communication (write a report).

Environmental considerations:

Design for recycling, net zero/Low carbon, design for service and repair, social equity and innovation.

Customer/stakeholder requirements:

Converting customer requests to a list of objectives and constraints

Interpretation of design requirements

Market analysis of existing products and competitors

Aspects of innovation and performance management in decision-making

Stakeholder engagement and communications in the context: Listening, non-verbal communication, clarity and brevity, friendliness, confidence, empathy, open-mindedness, respect, feedback, and picking the right medium; communication with groups including group expectations, dealing with reactions and disagreements, allowing and encouraging participation, acting on agreed outcomes, negative communication, motivating disillusioned colleagues, persuasion and negotiation.

LO2 **Analyse possible technical solutions to implement the proposed design specification**

Conceptual design and evaluating possible solutions:

Modelling, prototyping and simulation using industry standard software, (e.g., AutoCAD, Fusion 360, Catia, SolidWorks, Creo) on high specification computers

Sun systems and their integration into the final design

Use of evaluation and analytical tools, e.g., cause and effect diagrams, CAD, knowledge-based engineering; use relevant data management systems, databases, data formats, data analytics and workflows

Throughput, reliability, availability and maintainability (T-RAM)

Possible solutions using latest methods e.g. additive manufacturing, hot isostatic pressing (HIP)

Use of related documentation: job cards/build records, 2D & 3D drawing/models, Bill of Materials (BOM), Cost Analysis Reports, Compliance Report, Standard Operating Instructions (SOI's), Standard Process Instructions (POI's), Engineering Query Notifications (EQN's) and Drawing Query Notifications (DQN's).

LO3 **Produce a design report considering all key aspects including manufacturability (or design for manufacturing and assembly) and environmental impact**

Managing the design process:

Recognising limitations including cost, physical processes, availability of material/components and skills, timing, scheduling and design factors such as environmental impact and due considerations.

Working to specifications and standards, including:

The role of compliance checking, feasibility assessment, and commercial viability of product design through testing and validation

Analysing and interpreting data/information for documentation such as Parts Per Million (PPM) quality adherence, cost analysis and test data

Documentation control processes and procedures such as format, location, access, authorisation.

Design for testing, including:

Material selection to suit selected processes, tools, and technologies

Consideration of manufacturability, reliability, life cycle and environmental impact (e.g. UN sustainability goals)

The importance of safety, risk management, and ergonomics

Organisation approved Standard Operating Procedures (SOP's) and documentation recording systems, risk assessment, and the potential implications on safety, quality, and delivery if they are not adhered to.

Conceptual design and effective tools:

Technologies and manufacturing processes used in order to transfer engineering designs into finished products.

Design report:

Sample professional design reports and widely used professional formats, key sections of the report, referencing formats including citation.

LO4 **Present the design solution to an audience, including evaluation of feedback and future improvements**

Communication and post-presentation review:

Selection of communication/presentation tools/methods (e.g. formal and informal presentations, written reports, verbal, electronic, social media, data metrics), team presentation and management (e.g., team integration and dynamics, effective communications, conflict management).

Analysis of presentation feedback:

Strategies for improvement based on feedback, including systematic, proactive and transparent approach to improve design solutions.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Create a design specification for a given design brief that meets stakeholder's requirements, along with a proposed design solution		
P1 Create a design specification from a given design brief. **P2** Explain the influence of the stakeholder's design brief and requirements in the preparation of the design specification. **P3** Produce a design project schedule with a graphical illustration of the planned activities.	**M1** Evaluate potential planning techniques, presenting a case for the method chosen. **M2** Demonstrate critical path analysis techniques in design project scheduling/planning and explain their use.	**D1** Compare and contrast the completed design specification against a formal professional engineering specification.
LO2 Analyse possible technical solutions to implement the proposed design specification		
P4 Analyse industry standard evaluation and analytical tools used in formulating possible technical solutions. **P5** Use appropriate design techniques to produce a possible design solution.	**M3** Apply the principles of modelling, simulation and/or prototyping, using appropriate software, to develop an appropriate design solution.	**D2** Evaluate potential technical solutions, presenting a case for the final choice of solution.

Pass	Merit	Distinction
LO3 Produce a design report considering all key aspects including manufacturability (or design for manufacturing and assembly) and environmental impact		
P6 Prepare a formal engineering technical design report. **P7** Explain the role of design specifications and standards in the technical design report including environmental impact.	**M4** Assess any compliance, safety, and risk management issues contained within the technical design report.	**D3** Evaluate the effectiveness of the formal professional engineering technical design report for producing a fully compliant finished product.
LO4 Present the design solution to an audience, including evaluation of feedback and future improvements		
P8 Present the recommended design solution to the identified audience. **P9** Explain possible communication strategies and presentation methods that could be used to inform the stakeholders of the recommended solution.	**M5** Reflect on the effectiveness of the chosen communication strategy in presenting the design solution.	**D4** Justify potential improvements to the design solution and/or presentation based on reflection and/or feedback.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Barberio M., Colella M., Figliola A. and Battisti A. (Editors) (2023) *Architecture and Design for Industry 4.0: Theory and Practice − Lecture Notes in Mechanical Engineering* (Hardback). Springer.

Dul J. and Weerdmeester B. (2008) *Ergonomics for beginners*. 3rd Ed. Boca Raton: CRC Press.

Dym C.L., Little P. and Orwin E. (2014) *Engineering Design: a Project Based Introduction*. 4th Ed. Wiley.

Griffiths B. (2003) *Engineering Drawing for Manufacture*. Kogan Page Science.

Jack H. (2021) *Engineering Design, Planning, and Management*. 2nd Ed. Academic Press.

Leake J.M, Goldstein M.H., and Borgerson J.L. (2022) *Engineering Design Graphics: Sketching, Modeling, and Visualization*. 3rd Ed. Wiley.

Nassersharif B. (2022) *Engineering Capstone Design.* 1st Ed. CRC Press.

Planchard D.C. (2023) *Engineering Design with SOLIDWORKS 2023: A Step-by-Step Project Based Approach Utilizing 3D Solid Modelling*. 1st Ed. SDC Publications.

Pugh S. (1990) *Total Design: Integrated Methods for Successful Product Engineering*. 1st Ed. Prentice Hall.

Reddy K.V. (2008) *Textbook of Engineering Drawing*. 2nd Ed. Hyderabad: BS Publications.

Simmons C. H. (2012) *Manual of Engineering Drawing: Technical Product Specification and Documentation to British and International Standards*. 4th Ed. Butterworth-Heinemann.

Voland G (2014) *Engineering by Design*. 2nd Ed. Pearson.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

ASME Journal of Mechanical Design

Design Science

Journal of Engineering Design

Journal of Engineering Design and Technology

Research in Engineering Design

Links

This unit links to the following related units:

Unit 4023: Computer Aided Design and Manufacture (CAD/CAM)

Unit 5001: Research Project.

Unit 4002: Engineering Mathematics

Unit Code: A/651/0708

Level: 4

Credits: 15

Introduction

The mathematics that is delivered in this unit is directly applicable to the engineering and manufacturing industry, and it will help to increase students' knowledge of the broad underlying principles within this discipline.

The aim of this unit is to develop students' skills in the mathematical principles and theories that underpin the engineering curriculum. Students will be introduced to mathematical methods and statistical techniques in order to analyse and solve problems within an engineering and manufacturing context.

On successful completion of this unit, students will be able to employ mathematical methods within a variety of contextualised examples, interpret data using statistical techniques, and use analytical and computational methods to evaluate and solve engineering and manufacturing sector problems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Apply a variety of mathematical methods to a range of engineering and manufacturing sector problems

LO2 Investigate applications of statistical and probability techniques to interpret, organise, and present data

LO3 Use analytical and computational methods for solving engineering and manufacturing sector problems by relating sinusoidal wave and vector functions to their respective applications

LO4 Examine how differential and integral calculus can be used to solve engineering and manufacturing sector problems.

Essential Content

LO1 Apply a variety of mathematical methods to a range of engineering and manufacturing sector problems

Mathematical concepts:

Dimensional analysis

Arithmetic and geometric progressions

Complex Numbers.

Matrices

Functions:

Exponential, logarithmic, trigonometric, and hyperbolic functions.

Engineering and manufacturing sector examples:

Case studies with vocational scenarios, occupation/sector specific applications, modern industrial trends, needs and goals (e.g., sustainability, digitalisation).

LO2 Investigate applications of statistical and probability techniques to interpret, organise, and present data

Summary of data:

Data collection methods

Presentation of data − histograms; bar charts; line diagrams; cumulative frequency diagrams; scatter plots

Grouped and ungrouped data

Mean, mode, median, and standard deviation of data

Pearson's and Spearman's correlation coefficient

Linear regression, Classification methods, linear correlation coefficient and product moment correlation

Coordinate systems and reference frames

Effective data communication and representation methods/formats for stakeholder groups; accessible, inclusive, and diversity considerations and implications.

Hypothesis Testing:

Null hypothesis

Alternate hypothesis

Probability theory:

Conditional and unconditional probability

Binomial, Poisson, and normal distribution

Confidence intervals

Estimation of reliability and quality of engineering components and systems.

LO3 **Use analytical and computational methods for solving engineering and manufacturing sector problems by relating sinusoidal wave and vector functions to their respective applications**

Sinusoidal waves:

Sine waves and their applications

Trigonometric and hyperbolic identities.

Vector functions:

Vector notation and properties

Representing engineering quantities in vector form

Vectors in three dimensions.

Mathematical software for engineering and manufacturing sector:

Use of mathematical software packages (e.g. Mathcad, Microsoft Excel)

Confirmation of analytical results.

LO4 **Examine how differential and integral calculus can be used to solve engineering and manufacturing sector problems**

Differential calculus:

Definitions and concepts

Definition of a function and a derivative, graphical representation of a function, notation of derivatives, limits and continuity, derivatives; rates of change, increasing and decreasing functions and turning points

Differentiation of functions

Differentiation of functions including:

- standard functions/results
- using the chain, product, and quotient rules
- second order and higher derivatives

Types of function: polynomial, logarithmic, exponential, and trigonometric (sine, cosine, and tangent), inverse trigonometric and hyperbolic functions.

Integral calculus:

Definite and indefinite integration

Integrating to determine the area

Integration of functions including:

- common/standard functions
- using substitution
- by parts

Exponential growth and decay

Types of function: algebraic including partial fractions and trigonometric (sine, cosine, and tangent) functions

Engineering and manufacturing sector problems involving calculus:

Including: stress and strain, torsion, tolerancing, torque settings, motion, dynamic systems, oscillating systems, force systems, heat energy and thermodynamic systems, fluid flow, AC theory, electrical signals, information systems, transmission systems, electrical machines, electronics

Efficient problem-solving competencies in the chosen occupation/sector and effective written/verbal communication of solutions.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply a variety of mathematical methods to a range of engineering and manufacturing sector problems		**LO1 and LO2**
P1 Apply dimensional analysis techniques to solve complex engineering/manufacturing problems. **P2** Generate answers from engineering arithmetic and geometric progressions. **P3** Determine solutions of engineering equations using exponential, logarithmic, trigonometric, and hyperbolic functions.	**M1** Use three mathematical concepts to solve engineering/ manufacturing problems, justifying your chosen methods.	**D1** Present data as meaningful information using appropriate methods that can be understood by a non-technical audience.
LO2 Investigate applications of statistical and probability techniques to interpret, organise, and present data		
P4 Investigate engineering data by calculating mean, mode, median, and standard deviation. **P5** Calculate probabilities within Poisson, binomially and normally distributed engineering random variables.	**M2** Conduct an engineering hypothesis test and interpret the results.	

Pass	Merit	Distinction
LO3 Use analytical and computational methods for solving engineering and manufacturing sector problems by relating sinusoidal wave and vector functions to their respective applications		
P6 Solve engineering/ manufacturing problems relating to sinusoidal functions. **P7** Use appropriate methodology to determine engineering parameters of data represented in vector form.	**M3** Use compound angle identities to combine individual sine waves into a single wave, and illustrate graphically.	**D2** Apply engineering mathematical software to confirm the analytical solutions for at least three engineering/ manufacturing problems involving sinusoidal and vector functions.
LO4 Examine how differential and integral calculus can be used to solve engineering and manufacturing sector problems		
P8 Examine rates of change for a range of mathematical functions. **P9** Use integral calculus to determine a range of mathematical functions.	**M4** Solve a range of complex engineering/ manufacturing problems using both differential and integral calculus.	**D3** Evaluate a range of engineering/ manufacturing problems that involve second-order derivatives and the concept of maxima and minima.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird J. (2021) *Higher Engineering Mathematics*. 9th Ed. Routledge.

Bird J. (2019) *Science and Mathematics for Engineering*. 6th Ed. Routledge.

Glyn J. and Dyke P. (2020) *Modern Engineering Mathematics.* 6th edition. Pearson.

Made Easy Editorial Board (2022) *Engineering Mathematics for GATE 2023 and ESE 2023 (Prelims) – Theory and Previous Year Solved Papers*. India: Made Easy Publications Pvt Ltd.

Rattan K.S., Klingbeil N.W., and Baudendistel C.M. (2021) *Introductory Mathematics for Engineering Applications*. 2nd Ed. Wiley.

Ram M. (2021) *Recent Advances in Mathematics for Engineering.* CRC Press.

Teodorescu P., Stanescu N., and Pandrea N. (2013) *Numerical Analysis with Applications in Mechanics and Engineering.* Wiley-IEEE Press.

Ram M. (2020) *Mathematics in Engineering Sciences: Novel Theories, Technologies, and Applications.* 1st Edition. CRC Press.

Sobot, R. (2022) *Engineering Mathematics by Example*. 1st Ed. Springer.

Stroud, K.A. and Booth, D.J. (2020) *Engineering Mathematics*. 8th Ed. Bloomsbury Publishing

Urbano M. (2019) *Introductory Electrical Engineering with Math Explained in Accessible Language*. Wiley.

Vick B. (2020) *Applied Engineering Mathematics.* CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Annals of Mathematics

Computational Geometry

Communications on Pure and Applied Mathematics

International Journal of Engineering Mathematics

Journal of Computational and Engineering Mathematics

Journal of Engineering Mathematics

Journal of Geometry and Physics

Journal of Mathematical Physics

Links

This unit links to the following related units:

Unit 5006: Further Engineering Mathematics

Unit 4003: Engineering Science I

Unit Code: **J/651/0710**

Level: **4**

Credits: **15**

Introduction

Engineering is a discipline that uses scientific theory to design, develop, or maintain structures, machines, systems, and processes. Engineers are therefore required to have a broad knowledge of the science that is applicable to the industry around them.

This unit introduces students to the fundamental laws and applications of the physical sciences within engineering and how to apply this knowledge to find solutions to a variety of engineering problems.

Among the topics included in this unit are: international system of units, interpreting data, static and dynamic fundamentals, fluid mechanics and thermodynamics, material properties and failure, A.C./D.C. circuit theories, and electromagnetic principles and properties.

On successful completion of this unit, students will be able to interpret and present qualitative and quantitative data using computer software, calculate unknown parameters within mechanical and electrical systems, explain a variety of material properties, and use electromagnetic theory in an applied context.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine scientific data using both quantitative and qualitative methods

LO2 Apply the fundamentals of mechanical engineering systems

LO3 Explore the characteristics and properties of engineering materials

LO4 Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles, and properties.

Essential Content

LO1 Examine scientific data using both quantitative and qualitative methods

Quantitative research methodologies and methods:

Descriptive Research

Survey Research

Correlational Research

Quasi-experimental Research Design

Experimental Research

Relevant methodologies and methods.

Qualitative research methodologies and methods:

Grounded theory

Ethnographic

Narrative research

Historical

Case studies

Phenomenology

Relevant methodologies and methods.

The scientific method:

Question

Research

Hypothesis

Experiment

Data Analysis

Conclusion and Communication.

Interpreting data:

Investigation using the scientific method to gather appropriate data

Test procedures for physical (destructive and non-destructive) tests and statistical tests that might be used in gathering information

Summarising quantitative and qualitative data with appropriate graphical representations and appropriate use of an international system of units

Exploring the usage of quantitative and qualitative data in engineering applications specific to occupation/sector (e.g., manufacturing, operations, space systems, aeronautical engineering, etc.)

Using software to analyse data

Using presentation software to present data to an audience.

LO2 **Apply the fundamentals of mechanical engineering systems**

Static and dynamic fundamentals:

Units, scalars and vectors, two-dimensional force systems, and moment (torque) and couple

Representing loaded components with space and free-body diagrams

Equilibrium in two dimensions, distributed forces, the centre of mass, and centroids

Calculating support reactions of beams subjected to concentrated and distributed loads

Newton's laws of motion, one-dimensional particle kinematics, one-dimensional particle kinetics, D'Alembert's principle, and the principle of conservation of energy

Application of fundamentals and industrial case studies.

Fluid mechanics and thermodynamics:

Fluid definition and properties

Definition of pressure, hydrostatic pressure, and basic equations, manometry, application and calculations, Archimedes' principle

Flow characteristics and definitions, introduction to ideal fluid flow

Continuity of volume and mass flow for an incompressible fluid

Bernoulli's equation

Thermodynamic properties, temperature, the zeroth law of thermodynamic and pressure, system and control volume, processes, and cycles

Energy and energy transfer, and heat and work transfer: definitions, units, and sign convention

Ideal gas and equation of state, internal energy, enthalpy, and specific heats of ideal gas

The first law of thermodynamics.

LO3 **Explore the characteristics and properties of engineering materials**

Engineering materials:

Material properties, classifications, and testing

Atomic structure of materials and the structure of metals, polymers, and composites

Phase diagrams and analysis

Mechanical and electromagnetic properties of materials.

Material failure:

Destructive and non-destructive testing of materials

The effects of static, dynamic, and impact loading on a material

Degradation of materials and hysteresis.

Material selection:

Desired application

Working conditions

Manufacturability and assembly considerations

Cost and availability

Environmental impact and sustainability

Chemical and Physical properties.

LO4 **Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles, and properties**

D.C. circuit theory:

Ohm law, Kirchhoff's voltage and current laws

Voltage, current, resistance, power, and energy in D.C. networks composed of resistors, capacitors, and inductors.

Exploring circuit theorems (Thevenin, Norton, Mesh, Superposition, Maximum power transfer).

A.C. circuit theory:

Waveform characteristics in a single-phase A.C. circuit

Odd and even harmonics

VmaxSinω t ± α)

AC circuit analysis using Kirchhoff's laws

RLC circuits; Impedance, reactance, admittance, phasors, Q factor, bandwidth, and resonance in RLC circuits.

Magnetism:

Characteristics of magnetic fields and electromagnetic force

The principles and applications of electromagnetic induction, self and mutual induction, solenoid, relay, transformer, motors, and generators

Single and three-phase power, AC and DC motor and control.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine scientific data using both quantitative and qualitative methods		
P1 Examine at least three quantitative research methods. **P2** Examine at least three qualitative research methods.	**M1** Apply the scientific method within an engineering context that requires both quantitative and qualitative research methods.	**D1** Analyse scientific data employing both quantitative and qualitative methods, and using appropriate software and justified graphical representations.
LO2 Apply the fundamentals of mechanical engineering systems		
P3 Determine the support reactions of a beam carrying a combination of a concentrated load and a uniformly distributed load. **P4** Apply Archimedes and Bernoulli's principles in contextual engineering applications. **P5** Determine the ideal gas properties during a process.	**M2** Determine unknown forces by applying d'Alembert's principle to a free-body diagram.	**D2** Analyse thermodynamic systems with ideal gas by using the first law of thermodynamics.

Pass	Merit	Distinction
LO3 Explore the characteristics and properties of engineering materials		
P6 Explore the structural properties of metals and non-metals with reference to their material properties. **P7** Explain the types of degradation found in metals and non-metals.	**M3** Review elastic and electromagnetic hysteresis in different materials.	**D3** Analyse metals and non-metals for a given engineering application and fully justify the materials chosen.
LO4 Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles, and properties		
P8 Calculate currents, voltages, and power in D.C. circuits with more than one power source. **P9** Use software to produce complex waveforms combining two or more sinusoidal waveforms. **P10** Analyse problems on series and parallel RLC circuits with A.C. theory in creating solutions.	**M4** Explain the principles and applications of electromagnetic induction in at least three electrical devices and machines.	**D4** Evaluate different circuit theorems used to solve DC and AC circuit theory problems.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby M.F., Shercliff H., and Cebon D. (2023) *Introduction to Materials Science and Engineering: A Design-Led Approach.* 1st Ed. Butterworth-Heinemann.

Ashby M. F. and David R. H. J. (2012) *Engineering materials 1: an introduction to properties, applications, and design*. 4th Ed. Elsevier.

Bird J. (2012) *Science for Engineering*. 4th Ed. London: Routledge.

Bolton W. (2006) *Engineering Science*. 5th Ed. London: Routledge.

Callister Jr. W.D. and RETHWISCH D.G. (2019*) Callister's Materials Science and Engineering*. 10th Ed. Global Edition. Wiley.

Cengel Y. (2019) *Thermodynamics: an engineering approach SI*, 9th Ed. McGraw Hill.

Cengel Y. (2017) *Fluid Mechanics: Fundamentals and Applications*. 4th Ed. McGraw Hill.

Hayt W. H. (2023) *Engineering Circuit Analysis ISE.* 10th Ed. McGraw Hill.

Hibbeler R. C. (2017) *Engineering mechanics: Statics.* 14th Ed. Pearson.

Hibbeler R. C. (2016) *Engineering mechanics: dynamics.* 14th Ed. Pearson.

Schobeiri M. T. (2010). *Fluid mechanics for engineers: a graduate textbook*. Springer Science & Business Media.

Tooley M. and Dingle L. (2012) *Engineering Science: For Foundation Degree and Higher National*. London: Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Applications in Engineering Science

Engineering Reports

International Journal of Engineering Science

International Journal of Engineering Technology and Scientific Innovation

International Journal of Mechanical Sciences

Links

This unit links to the following related units:

Unit 4009: Materials, Properties and Testing

Unit 4002: Engineering Design

Unit 4092: Engineering Science II

Unit 4004: Managing a Professional Engineering Project

Unit Code: L/651/0712

Level: 4

Credits: 15

Introduction

The responsibilities of the engineer go far beyond completing the task in hand. Reflecting on their role in a wider ethical, environmental, and sustainability context starts the process of becoming a professional engineer – a vital requirement for career progression.

Engineers seldom work in isolation and most tasks they undertake require a range of expertise, designing, developing, manufacturing, constructing, operating, and maintaining the physical infrastructure and content of our world. The bringing together of these skills, expertise, and experience is often managed through the creation of a project.

This unit introduces students to the techniques and best practices required to successfully create and manage an engineering/manufacturing project designed to identify a solution to an engineering need. While carrying out this project students will consider the role and function of engineering in our society, the professional duties and responsibilities expected of engineers together with the behaviours that accompany their actions.

Among the topics covered in this unit are: roles, responsibilities, and behaviours of a professional engineer, planning a project, project management stages, devising solutions, theories and calculations, management using a Gantt chart, evaluation techniques, communication skills, and the creation and presentation of a project report.

On successful completion of this unit, students will be able to conceive, plan, develop, and execute a successful engineering project, and produce and present a project report outlining and reflecting on the outcomes of each of the project processes and stages. As a result, they will develop skills such as critical thinking, analysis, reasoning, interpretation, decision-making, information literacy, and information and communication technology, and skills in professional and confident self-presentation.

This unit is assessed by a Pearson-set theme. The project brief will be set by the centre, based on a theme provided by Pearson (this will change annually). The theme and chosen project within the theme will enable students to explore and examine a relevant and current topical aspect of professional engineering.

***Please refer to the accompanying Pearson-set Assignment Guide and the Theme Release document for further support and guidance on the delivery of the Pearson-set unit.**

Learning Outcomes

By the end of this unit students will be able to:

LO1 Select a project that will provide a solution to an identified engineering/manufacturing problem.

LO2 Conduct planned project activities to generate outcomes which provide a solution to the identified engineering/manufacturing problem.

LO3 Produce a project report analysing the outcomes of each of the project processes and stages.

LO4 Present the project report drawing conclusions on the outcomes of the project.

Essential Content

LO1 **Select a project that will provide a solution to an identified engineering/manufacturing problem**

Engineering projects:

Overview of project management

Examples of realistic engineering/manufacturing-based problems

Grand engineering/manufacturing challenges (e.g., regional, global, sector, society); relevant case studies

Crucial considerations for the project

How to identify the nature of the problem through vigorous research

Feasibility study to identify constraints and produce an outline specification

Project management techniques ‒ Strengths, Weaknesses, Opportunities, Threats (SWOT), stakeholder matrices, risk mapping, radar chart, and summary risk profiles.

Team-driven problem solving: positive, professional, respectful, trusting and ethical working relationships. Impact of human factors (i.e., organisational, environment and job factors) on individual/team behaviours and performance. Team support (e.g., coaching/mentoring, feedback, opportunities). Organisational vision and goals. Holistic stakeholder engagement.

Develop an outline project brief and design specification:

Knowledge theories, calculations and other relevant information that can support the development of a potential solution

Project selection relevant to occupation/sector of interest/programme of study (e.g., mechanical, electrical, manufacturing, aeronautical, operations, space, marine, Industry 4.0, automation, computer systems etc.).

Ethical frameworks:

The Engineering Council and Royal Academy of Engineering's Statement of Ethical Principles

The National Society for Professional Engineers' Code of Ethics.

Professional, Statutory and Regulatory Bodies (PSRBs):

Global, national, and regional influences on engineering/manufacturing, and the role of the engineer. For example: The Royal Academy of Engineering and the UK Engineering Council.

The role and responsibilities of the PSRBs. For example, UK Engineering Council and the Professional Engineering Institutions (PEIs)

Roles: Chartered Engineer, Incorporated Engineer, and Engineering Technician, other professional body membership roles, requirements for eligibility and responsibilities

Standards and content of the standards. For example, the content of the UK Standard for Professional Engineering Competence (UKSPEC)

Occupational standards and alignment with knowledge, skills, and behaviours of a chosen occupation.

International regulatory regimes and agreements associated with professional engineering:

European Federation of International Engineering Institutions.

European Engineer (Eur Eng)

European Network for Accreditation of Engineering Education

European Society for Engineering Education

International Council on Systems Engineering

The Institute of Industrial and Systems Engineers (IISE)

Washington Accord

Dublin Accord

Sydney Accord

International Engineers Alliance

Asia Pacific Economic Cooperation (APEC) Engineers Agreement.

LO2 **Conduct planned project activities to generate outcomes which provide a solution to the identified engineering/manufacturing problem**

Project execution phase:

Continually monitoring development against the agreed project plan and adapting the project plan where appropriate

Work plan and time management, using Gantt chart or similar. Prioritisation of workload/time management techniques to achieve personal and team objectives. Role of KPIs.

Integrated quality control checks (including risk assessments and resolutions)

Tracking costs and timescales

Maintaining a project diary to monitor progress against milestones and timescales.

Engineering professional behaviour sources:

Professional responsibility for health and safety (e.g., UK-SPEC)

Professional standards of behaviour (e.g., UK-SPEC)

Relevant government and organisational policies, legal requirements (e.g., employment law, equality law), implications, and compliance.

Ethical frameworks:

The Engineering Council and Royal Academy of Engineering's Statement of Ethical Principles

The National Society for Professional Engineers' Code of Ethics.

LO3 **Produce a project report analysing the outcomes of each of the project processes and stages**

Convincing arguments:

All findings/outcomes should be convincing and presented logically where the assumption is that the audience has little or no knowledge of the project process.

Critical analysis and evaluation techniques:

Most appropriate evaluation techniques to achieve a potential solution

Use of data collection systems, data formats, and dashboards Secondary and primary data should be critiqued and considered with an objective mindset

Objectivity results in more robust evaluations where an analysis justifies a judgement and decision making.

LO4 **Present the project report drawing conclusions on the outcomes of the project**

Presentation considerations:

Media selection, what to include in the presentation and what outcomes to expect from it. Audience expectations and contributions

Presentation specifics. Audience: project supervisors, fellow students and employers and others involved. Time allocation, structure of presentation

Reflection on project outcomes and audience reactions

Conclusion to report, recommendations for future work, lessons learned, changes to own work patterns.

Reflection for learning and practice:

The difference between reflecting on performance and evaluating a project − the former considers the research process, information gathering and data collection, the latter the quality of the research argument and use of evidence.

The cycle of reflection:

To include reflection in action and reflection on action

How to use reflection to inform future behaviour, particularly directed towards sustainable performance

The importance of Continuing Professional Development (CPD) in refining ongoing professional practice. Reflecting on competencies gained. Keeping abreast of developments in engineering/manufacturing processes manufacturing and emerging technologies through reskilling/upskilling (e.g., digital competencies, sustainability goals).

Reflective writing:

Avoiding generalisation and focusing on personal development and the research journey critically and objectively.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Select a project that will provide a solution to an identified engineering/manufacturing problem</td><td rowspan="2">D1 Illustrate the effect of legislation and ethics in developing the project plan.</td></tr>
<tr><td>P1 Select an appropriate engineering/manufacturing-based project, giving reasons for the selection

P2 Create a project plan for the engineering/manufacturing project.</td><td>M1 Undertake a feasibility study to justify project selection.</td></tr>
<tr><td colspan="2">LO2 Conduct planned project activities to generate outcomes which provide a solution to the identified engineering/manufacturing problem</td><td rowspan="2">D2 Critically evaluate the success of the project plan, making recommendations for improvement.</td></tr>
<tr><td>P3 Conduct project activities, recording progress against the original project plan.</td><td>M2 Explore alternative methods to monitor and meet project milestones, and justify selection of chosen method(s).</td></tr>
<tr><td colspan="2">LO3 Produce a project report analysing the outcomes of each of the project processes and stages</td><td rowspan="4">LO3 and LO4

D3 Critically analyse the project outcomes, making recommendations for further development.</td></tr>
<tr><td>P4 Produce a project report covering each stage of the project and analysing project outcomes.</td><td>M3 Use appropriate critical analysis and evaluation techniques to analyse project findings.</td></tr>
<tr><td colspan="2">LO4 Present the project report drawing conclusions on the outcomes of the project</td></tr>
<tr><td>P5 Present the project activities and outcomes using appropriate media to an audience.</td><td>M4 Analyse own behaviours and performance during the project activities and suggest areas for improvement</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Aucoin B.M. (2018) *From Engineer to Manager: Mastering the Transition.* Second Edition Hardcover – Unabridged. Artech House.

Del Pont J.P. (2012) *Process Engineering and Industrial Management.* Wiley.

Kerzner H. (2023) *Project Management Metrics, KPIs, and Dashboards: A Guide to Measuring and Monitoring Project Performance*. 4th Edition. Wiley.

Kerzner H. (2022) *Innovation Project Management: Methods, Case Studies, and Tools for Managing Innovation Projects*. 2nd Edition. Wiley.

Pugh P. S. (1990) *Total Design: Integrated Methods for Successful Product Engineering*. Prentice Hall.

Striebig B., Ogundipe A. and Papadakis M. (2015) *Engineering Applications in Sustainable Design and Development*. Cengage Learning.

Ulrich K. and Eppinger S. (2011) *Product Design and Development*. 5th Ed. McGraw-Hill Higher Education.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Engineering Management

Engineering Management Journal

Frontiers of Engineering Management

IEEE Transactions on Engineering Management

International Journal of Engineering and Technology

Journal of Engineering Design

Journal of Engineering, Design and Technology

Journal of Engineering and Technology Management

Journal of Manufacturing Technology Management

Journal of Management & Organization

Microelectronic Engineering

Probability in the Engineering and Information Sciences

[Probabilistic Engineering Mechanics]

[Results in Engineering]

Links

This unit links to the following related units:

Unit 5001: Research Project

Unit 5002: Professional Engineering Management

Unit 4005: Renewable Energy

Unit Code: R/651/0714

Level: 4

Credits: 15

Introduction

With the increasing concerns regarding climate change arising from increasing carbon dioxide levels and other adverse environmental impacts of industrial processes, there are widespread economic, ethical, legislative and social pressures on engineers to develop technologies and processes that have reduced carbon and environmental impact.

This unit aims to familiarise students with both established and emerging renewable energy resources and technologies. It will delve into current and future storage and generation systems, critically exploring their capabilities and constraints.

On successful completion of this unit, students will be able to determine the optimum combination of renewable energy technologies and evaluate their efficiencies, describe how to conduct a cost–benefit analysis to determine the most viable option between renewable and conventional energy sources, and consider the relevant political, socio-economic, and legal factors that influence the selection of appropriate energy technologies.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explore potential renewable energy resources and technologies

LO2 Determine the optimum combination and efficiencies of renewable energy technologies for a particular location

LO3 Conduct a cost-benefit analysis to determine the most viable option between renewable and conventional energy sources

LO4 Analyse the socio-economic, legislative, and environmental factors in selecting appropriate renewable energy technologies.

Essential Content

LO1 **Explore potential renewable energy resources and technologies**

Alternative energy resources, their respective merits, and drawbacks:

Wind energy, ocean and tidal energy, biomass, geothermal energy, hydropower, solar photovoltaic, solar thermal energy, and waste-to-energy.

Energy storage and generation technologies (e.g., batteries, hydrogen).

LO2 **Determine the optimum combination and efficiencies of renewable energy technologies for a particular location**

Energy demand and security of supply:

Energy consumption changes, intensity and trends (domestic, industrial, transport, and services sectors)

Factors affecting changes in energy consumption and demand

Future demand planning based on trends and needs analysis

Risk analysis for energy supplies for local areas and global regions

Energy capacity margins analysis related to changes in demand

Alternatives for locally used energy sources.

Energy reduction and efficiency approaches:

Energy systems available for a given location

Energy legislation and standards

Energy saving and reduction schemes, energy saving technologies available

Energy efficiency approaches for domestic energy use

Grants and government schemes, and the effects of such schemes on supply and demand.

Grid Integration Requirements:

Local Grid Code requirements and compliance for integration of the renewable energy assets

LO3 **Conduct a cost-benefit analysis to determine the most viable option between renewable and conventional energy sources**

Financial and environmental implications:

Cost-benefit analysis using appropriate tools and techniques

Socio-economic factors

Financial implications of renewable and conventional energy.

LO4 **Analyse the socio-economic, legislative, and environmental factors in selecting appropriate renewable energy technologies.**

Set-up and operation of renewable technologies:

Socio-economic factors (e.g. UN sustainability goals)

Legislative and commercial considerations, including carbon taxes and national and international climate change legislation

Environmental factors

Evaluation planning tools such as PESTLE analysis

Local environmental impact and considerations

Waste impact, waste management strategies

Contamination issues and society wellbeing.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore potential renewable energy resources and technologies		
P1 Explore potential renewable energy resources suitable for your local area and their working principles with the aid of diagrams.	**M1** Analyse storage technologies and their advantages and disadvantages in relation to at least three different forms of renewable energy.	**D1** Evaluate a wide variety of renewable energy resources, with innovative insights into their potential future usage.
LO2 Determine the optimum combination and efficiencies of renewable energy technologies for a particular location		
P2 Determine the most efficient combination of renewable energy technologies for a specified location.	**M2** Analyse the location's specific environmental and geographical factors and how they relate to the efficiency of different renewable energy technologies.	**D2** Propose an innovative, well-justified combination of renewable energy technologies for the specific location, taking into account not only efficiency but also factors such as sustainability, cost-effectiveness and societal impact.

Pass	Merit	Distinction
LO3 Conduct a cost-benefit analysis to determine the most viable option between renewable and conventional energy sources		
P3 Conduct cost-benefit analysis that considers the direct costs and benefits of both renewable and conventional energy sources.	**M3** Effectively incorporate indirect costs and benefits such as environmental impacts and potential societal benefits and drawbacks into the cost-benefit analysis.	**D3** Present a thorough and nuanced cost–benefit analysis that considers both short-term and long-term impacts, as well as contingencies and uncertainties, with a well-argued recommendation based on the analysis.
LO4 Analyse the socio-economic, legislative, and environmental factors in selecting appropriate renewable energy technologies.		
P4 Analyse how socio-economic, legislative, and environmental factors influence the selection of appropriate renewable energy technologies, for a given local context.	**M4** Provide a detailed analysis of specific socio-economic, legislative, and environmental factors and their impact on selecting renewable energy technologies in a global context.	**D4** Evaluate the impact of socio-economic, legislative and environmental factors on selecting renewable energy technologies, using relevant, real-world examples and forecasting potential future trends.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Andrews, J. and Jelley, N. (2013) *Energy Science: Principles, Technologies and Impacts*. 2nd Ed. Oxford University Press.

Boyle G. (2012). *Renewable Energy: Power for a Sustainable Future.* 4th Ed. Oxford, UK: Oxford University Press.

Kolhe M.L. (Editor) (2022) *Renewable Energy Systems in Smart Grid: Select Proceedings of International Conference on Renewable and Clean Energy (ICRCE) 2022 − Lecture Notes in Electrical Engineering 938 (Paperback).* Springer Verlag.

Kularatna N. (2020) *Energy Storage Devices for Renewable Energy.* Elsevier.

Manwell J.F., McGowan J.G., and Rogers A.L. (2009) *Wind Energy Explained: Theory, Design and Application.* 2nd Ed. Wiley.

McCartney D. (Editor) (2023) *Renewable Energy Sources: Engineering and Technology (Hardback).* States Academic Press.

Moore E.A. (2022) *Explaining Renewable Energy (Paperback).* Taylor & Francis Ltd.

Nahhas A.M.A. and Ibhadode A.O.A. (Editors) (2023) *Renewable Energy: Recent Advances (Hardback).* IntechOpen.

Nelson V.C. (2011). *Introduction to Renewable Energy. 2nd Ed. CRC Press.*

Olabi A.G.(Editor) (2023) *Renewable Energy − Volume 2: Wave, Geothermal, and Bioenergy: Definitions, Developments, Applications, Case Studies, and Modelling and Simulation* (Paperback). Elsevier.

Shere J. (2013) *Renewable: The World-Changing Power of Alternative Energy. St. Martin's Griffin.*

Smets A. Jäger K., Isabella O., Swaaij R.V., and Zeman M. (2016) *Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems.* UIT Cambridge Ltd.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Renewable Energy Focus Journal

Journal of Renewable and Sustainable Energy

Renewable and Sustainable Energy: An International Journal

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4089 Net Zero Energy Technologies I: Systems and Demand

Unit 5011: Industrial Power, Electronics and Storage

Unit 5018: Sustainability

Unit 5054: Net Zero Energy Technologies II: Infrastructure and Pathways.

Unit 4006: Mechatronics

Unit Code: Y/651/0716

Level: 4

Credits: 15

Introduction

Auto-focus cameras, car cruise control and automated airport baggage handling systems are examples of mechatronic systems. Mechatronics is the combination of mechanical, electrical, and computer/controlled engineering working together in automated systems and 'smart' product design.

Among the topics included in this unit are: consideration of component compatibility, constraints on size and cost, control devices used, British and/or European standards relevant to application, sensor types and interfacing, simulation and modelling software functions, system function and operation, advantages and disadvantages of software simulation, component data sheets, systems drawings, flowcharts, wiring and schematic diagrams.

On successful completion of this unit students will be able to learn about the basic mechatronic system components and functions, designing a simple mechatronic system specification for a given application, appropriate simulation and modelling software to examine its operation and function, and solving faults on mechatronic systems using a range of techniques and methods.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the design and operational characteristics of a mechatronic system

LO2 Produce a mechatronic system design specification for a given application

LO3 Examine the operation and function of a mechatronics system using simulation and modelling software

LO4 Demonstrate fault finding skills and fault analysis on a mechatronic system.

Essential Content

LO1 Explain the design and operational characteristics of a mechatronic system

Origins and evolution:

History and early development, evolution

Industrial and consumer examples of mechatronic systems

Extent of mechatronic systems use

Current operational abilities and anticipated improvements.

Systems characteristics:

Design of systems in an integrated way

Design systems to optimise performance

Design systems using emerging technologies, Industry 4.0 and analyse impact on organisations

Sensor and transducer types used

Consideration of component compatibility

Constraints on size and cost

Control device requirements and examples of applications.

LO2 Produce a mechatronic system design specification for a given application

Systems specifications:

British and/or European standards relevant to application

Electrical system circuit diagrams, operation of the various components that make up mechatronic system, understanding technical documents

Sensor types and interfacing

Actuator technology availability and selection

Selection and use of appropriate control software/devices.

Consideration of the interaction of system variables

System commissioning parameters.

LO3 **Examine the operation and function of a mechatronics system using simulation and modelling software**

Operation and functions:

Simulation and modelling software functions

System function and operation

Modes of operation simulation, loading and surges

Advantages and disadvantage of software simulation.

LO4 **Demonstrate fault finding skills and fault analysis on a mechatronic system**

Locating and correcting system faults:

Component data sheets, systems drawings, flowcharts, wiring and schematic diagrams, technical documentation (e.g. manuals), fault reports

Within the context − effective use of data collection systems (e.g. databases), data management systems, data analytics and dashboards; documentation control processes and procedures (e.g., format, location, access, authorisation)

Original system correct function and operation

Instrumentation usage and faults: multimeter, flowmeter, temperature measurement, pressure meter etc. and the measurement data transmission

Inspection and testing using methodical fault location techniques and methods, use of control software to aid fault location

Identification, evaluation and verification of faults and their causes, rectification, final system testing and return to service

Safety first culture in using equipment and resolving the faults − health and safety policies, procedures and regulations, compliance, risk assessment processes and procedures, risk mitigation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the design and operational characteristics of a mechatronic system		
P1 Explain the key requirements and components of a given mechatronics system **P2** Explain the types of actuators, sensors and transducers used in a given mechatronics system.	M1 Analyse how the components operate as part of an integrated mechatronic system. M2 Analyse the methods of control used by the mechatronic system.	**D1** Evaluate the mechatronic system specification and propose an alternative solution.
LO2 Produce a mechatronic system design specification for a given application		
P3 Produce a design specification for a given mechatronic system application including the details of the sensor and actuator technologies.	**M3** Justify the sensor and actuator technologies selected with reference to available alternatives.	**D2** Evaluate the operational capabilities and limitations of the mechatronic system design specification produced.
LO3 Examine the operation and function of a mechatronics system using simulation and modelling software		
P4 Examine the operation and function of a given mechatronics system using industry standard simulation/modelling software.	**M4** Analyse the operation and function of a simulated/ modelled mechatronics system, with improvements to the system.	**D3** Evaluate the advantages and disadvantages of the simulation/modelling software used, based on the results obtained, with recommended improvements.
LO4 Demonstrate fault finding skills and fault analysis on a mechatronic system		
P5 Explain the safe use of fault finding test equipment **P6** Demonstrate fault finding analysis by locating and rectifying faults on a given mechatronic system.	**M5** Apply and document the safe and correct use of fault-finding equipment and techniques/methods on a given mechatronic system.	**D4** Investigate the causes of faults in a given mechatronic system, with suggested amendments to the design specification to improve system reliability.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Alciatore D.G. and Histand M.B. (2019) *Introduction to Mechatronics and Measurement Systems.* 5th Ed. McGraw-Hill.

Bolton W. (2018) *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*. 7th Ed. Pearson Education Limited.

Hami A.E. and Pougnet P. (2020) *Embedded Mechatronic Systems 2: Analysis of Failures, Modeling, Simulation and Optimization*. 2nd Ed. ISTE Press – Elsevier.

Indri M. and Oboe R. (2022) *Mechatronics and Robotics: New Trends and Challenges.* 1st Ed. CRC Press.

Lyshevski S.E. (2020) *Mechatronics and Control of Electromechanical Systems.* 1st Ed. CRC Press.

Mahalik N.P. (2010) *Mechatronics: Principles, Concepts and Applications*. New Delhi: McGraw-Hill.

Onwubolu G.C. (2005) *Mechatronics: Principles and Applications*. Oxford: Elsevier.

Ramachandran K.P., Vijayaraghavan G.K. and Balasundaram M.S. (2008) *Mechatronics: Integrated Mechanical Electronic Systems*. India: Wiley.

Singh S.B., Ranjan P. and Haghi A.K. (2022) *Applied Mechatronics and Mechanics: System Integration and Design*. 1st Ed. Apple Academic Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

IEEE/ASME Transactions on Mechatronics

IET Robotics and Mechatronics Network

International Journal of Advanced Mechatronic Systems

Journal of Mechatronics and Robotics

Journal of Mechatronics Engineering

Mechatronics

Links

This unit links to the following related units:

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 5021: Further Control Systems Engineering.

Unit 4007: Machining and Processing of Engineering Materials

Unit Code: D/651/0718

Level: 4

Credits: 15

Introduction

Practical articles that we see and use every day such as automobiles, aircraft, trains, and even the cans we use to store our food, came from the ideas and visions of engineers and designers. The production of these articles is based on well-established production processes, machines, and materials.

The aim of this unit is to introduce students to the application of a variety of material forming processes involved in the production of components and articles for everyday use. Among the topics included in this unit are: conventional machining, additive layer manufacturing (ALM), shaping and moulding processes used in the production of components, machine tooling, jigs and fixtures required to support the manufacture of components, using metallic and non-metallic materials such as polymers and composites.

On successful completion of this unit students will be able to describe moulding, shaping, and forging, ALM manufacturing processes, explain the importance of material selection, and summarise the impact machining processes have on the physical properties of a component.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explore the conventional machining, additive manufacture and forming processes and their application in the production of engineered components

LO2 Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process

LO3 Examine the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component

LO4 Discuss the most appropriate moulding and shaping process used to produce a range of metal and non-metal engineered components.

Essential Content

LO1 **Explore the conventional machining, additive manufacture and forming processes and their application in the production of engineered components**

Manufacturing processes:

Material removal machining processes including: conventional manual processes, CNC machining and erosion machining technologies

Selection of machining processes to generate geometrical forms: flat and cylindrical geometry

Additive manufacture principles, techniques (e.g., 3D printing,), processes and applications; virtual machining/forming technologies and example case studies

Impact of material removal rate on surface finish and texture and speed of production

Consideration of the effect of production volume (prototypes, batch, and high volume) on the selection of the most appropriate process, tooling and resource commitment

Safe working practices when operating machining and process forming equipment.

LO2 **Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process**

Material choice and machine process:

Impact of material types on the choice of machining process including: round, square and hexagonal bar, tube, plate, section and pre-cast

Effective of post processing activities of additive layer manufactured parts, e.g. hot isostatic pressing and shot peening.

Machining characteristics when using polymers, composites, non-ferrous and ferrous metals and exotic materials

Composites for machining/forming, latest advancements in composites

How the mechanical properties of the component material can be affected by the machining process

Effect of lubricants, coolants and cutting fluids on tooling, production speed, and quality of finish.

LO3 **Examine the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component**

Awareness of the range of cutting tools:

Factors that prolong tool life, increased material removal rate and improved surface finish

Properties for cutting tool materials

Cause and effect of premature and catastrophic tool failure, preventative measures to promote tool life.

Cutting forces and the mechanics of chip formation:

Factors that affect cutting speeds and feeds, calculating cutting speeds and feeds

Relationship between cutting speed and tool life, economics of metal removal

Range of tooling jigs and fixtures including mechanical, magnetic, hydraulic and pneumatic

Work-holding: six degrees of freedom.

LO4 **Discuss the most appropriate moulding and shaping process used to produce a range of metal and non-metal engineered components**

Moulding and shaping processes:

Range of metal and ceramic powder moulding and shaping processes

Casting, powder metallurgy and sintering

Range of plastic moulding and shaping processes: blow, compression, extrusion, injection, laminating, reaction injection, matrix, rotational, spin casting, transfer and vacuum forming

Discuss in groups industry case studies and good practices in producing metal and non-metal engineered components.

Range, benefits and limitations of various shaping processes:

Extrusion, forging, rolling, hot and cold presswork.

Range of casting processes:

Sand, permanent mould, investment, lost foam, die, centrifugal, glass and slip casting.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explore the conventional machining, additive manufacture and forming processes and their application in the production of engineered components</td><td rowspan="2">D1 Evaluate the benefits and limitations of components manufactured using conventional machining, additive manufacture and moulding processes.</td></tr>
<tr><td>P1 Explain the most appropriate machining or additive manufacture process to manufacture a selected component

P2 Explore the reasons why a specific moulding process would be used to manufacture a selected component.</td><td>M1 Analyse the characteristics of conventional machining processes, additive manufacture processes, plastic moulding processes and powder metallurgy used in producing components.</td></tr>
<tr><td colspan="2">LO2 Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process</td><td rowspan="2">D2 Evaluate the structure and mechanical properties of a given engineered component manufactured using the die-casting process and conventional material-removal machining processes.</td></tr>
<tr><td>P3 Explain how the manufacturing process can affect the structure and properties of the parent material

P4 Describe the effect lubricants, coolants and cutting fluids have on tooling, production speed, and quality of finish.</td><td>M2 Detail the characteristics of cutting tool geometries

M3 Examine why different tool geometries are required for different material types.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Examine the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component		
P5 Examine the parameters of metal removal that determine the appropriate tooling for the production of a given engineered component **P6** Describe the range of tooling jigs and fixtures needed to retain a component during manufacture to mitigate possible failures linked to the cutting tools employed during the process.	**M4** Analyse the properties and modes of failure of modern cutting tools used in machining operations.	**D3** Critique the relationship between metal removal rate and tool life on the economics of material removal.
LO4 Discuss the most appropriate moulding and shaping process used to produce a range of metal and non-metal engineered components.		
P7 Explain which material characteristics determine the choice of moulding processes **P8** Discuss the benefits and limitations of products manufactured by sintering and moulding processes.	**M5** Analyse each of the stages of the moulding process and comment on the benefits associated with this manufacturing process.	**D4** Evaluate how the composition and structure of metal alloys, polymers and polymer matrix composites are affected by the material machining or forming process.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bhattacharyya B. and Doloi B. (2019) *Modern machining technology: Advanced, hybrid, micro machining and super finishing technology*. Academic Press.

Chang K.H. (2021) *Virtual Machining Using CAMWorks 2021: CAMWorks as a solidworks Module*. 1st Ed. SDC Publications.

Gajrani K.K., Prasad A. and Kumar A. (2022) *Advances in Sustainable Machining and Manufacturing Processes.* 1st Ed. CRC Press.

Gibson I., Rosen D., Khorasani M. and Stucker B. (2020) *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing*. 3rd Ed. Cham, Switzerland: Springer Nature.

Groover M.P. (2020) *Fundamentals of Modern Manufacturing: Materials, Processes, And Systems*. John Wiley and Sons.

Gupta K. and Davim J.P. (2020) *High-Speed Machining.* 1st Ed. Academic Press.

Huda Z. (2021) *Machining Processes and Machines: Fundamentals, Analysis, and Calculations*. 1st Ed. CRC Press.

Kalpakjian S. and Schmid R.S. (2013) *Manufacturing Engineering and Technology*. 7th Ed. Pearson.

Nayak R.K., Pradhan M.K. and Sahoo A.K. (2022) *Machining of Nanocomposites.* 1st Ed. CRC Press.

Pramanik A. (2021) *Machining and Tribology: Processes, Surfaces, Coolants, and Modeling.* 1st Ed. Elsevier.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

International Journal of Machining and Machinability of Materials

International Journal of Machine Tools and Manufacture

Journal of Materials: Design and Applications,

Machining Science and Technology

Links

This unit links to the following related units:

Unit 4009: Materials, Properties and Testing

Unit 4010: Mechanical Workshop Practices.

Unit 4008: Mechanical Principles

Unit Code: K/651/0720

Level: 4

Credits: 15

Introduction

Mechanical principles have been crucial for engineers to convert the energy produced by burning oil and gas into systems to propel, steer and stop our automobiles, aircraft, and ships, amongst thousands of other applications. The knowledge and application of these mechanical principles is still the essential underpinning science of all machines in use today or being developed into the latest technology.

The aim of this unit is to introduce students to the essential mechanical principles associated with engineering applications.

Topics included in this unit are: behavioural characteristics of static, dynamic and oscillating engineering systems including shear forces, bending moments, torsion, linear and angular acceleration, conservation of energy and vibrating systems; and the movement and transfer of energy by considering parameters of mechanical power transmission systems.

On successful completion of this unit students will be able to learn about the underlying principles, requirements, and limitations of mechanical systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Solve problems within static mechanical systems

LO2 Analyse dynamic mechanical systems

LO3 Investigate elements of simple mechanical power transmission systems

LO4 Analyse natural and damped vibrations within translational and rotational mass-spring systems.

Essential Content

LO1 **Solve problems within static mechanical systems**

Shafts and beams:

The effect of shear forces on beams

Bending moments and stress due to bending in beams

Selection of appropriate rolled steel sections to satisfy given specifications for beams and columns

The theory of torsion in solid and hollow circular shafts

Stress and deflection in solid and hollow circular shafts due to torsion

Impact of stresses in different types of materials

Introduction to stresses in pressure vessels

Use of relevant problem-solving tools within the context e.g. root cause analysis (RCA), process failure modes effects analysis (PFMEA), fishbone, practical problem solving (PPS), advanced product quality planning (APQP)

Use of relevant software and simulation tools within the context.

LO2 **Analyse dynamic mechanical systems**

Energy and work:

The principle of conservation of energy and work-energy transfer in systems

Linear and angular velocity and acceleration

Velocity and acceleration diagrams of planar mechanisms

Gyroscopic motion

Examples and applications of dynamic systems and gyroscopic motion.

LO3 **Investigate elements of simple mechanical power transmission systems**

Simple systems/subsystems:

Parameters of simple and compounded geared systems

Efficiency of lead screws and screw jacks.

Couplings and energy storage:

Universal couplings and conditions for constant-velocity

Importance of energy storage elements and their applications including electro-mechanical systems

Examples and applications of current mechanical power transmission systems/subsystems.

LO4 **Analyse natural and damped vibrations within translational and rotational mass-spring systems**

Types of motion:

Simple harmonic motion

Natural frequency of vibration in mass-spring systems.

Damped systems:

Frequency of damped vibrations in mass-spring-damper systems

The conditions for an external force to produce resonance

Examples and applications of mechanical vibrations (e.g., modelling of vibration isolation, vehicle suspensions).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Solve problems within static mechanical systems		
P1 Solve mechanical systems problems that include distribution of shear force, bending moment and stress due to bending in simply supported beams **P2** Justify the selection of standard rolled steel sections for beams and columns **P3** Calculate the distribution of shear stress and the angular deflection due to torsion in solid and hollow circular shafts.	**M1** Determine the material used for a circular bar using experimental data obtained from a torsion test for the angle of twist under loading.	**D1** Verify, using simulation software, analytical calculations of the magnitude of shear force and bending moments in cantilever and encastre beams for given design applications.
LO2 Analyse dynamic mechanical systems		
P4 Analyse the energy transfer processes within mechanical systems that are operating in uniform acceleration motion **P5** Analyse the magnitude and effect of gyroscopic reaction torque.	**M2** Analyse dynamic aspects of given mechanical system(s) using vector diagrams of velocities and accelerations within planar mechanisms.	**D2** Evaluate the behaviour of mechanical dynamic systems by applying appropriate methodologies.

Pass	Merit	Distinction
LO3 Investigate elements of simple mechanical power transmission systems		**D3** Evaluate the cause of a documented case of mechanical power transmission failure, and the steps to correct the problem and to rectify any design faults.
P6 Investigate the behaviour of compound gear systems and the holding torque required to securely mount a gearbox **P7** Investigate the operating efficiency of lead screws and screw jacks **P8** Explain the conditions required for a constant velocity ratio between two joined shafts.	**M3** Examine devices which function to store mechanical energy in their operation.	
LO4 Analyse natural and damped vibrations within translational and rotational mass-spring systems		**D4** Determine the conditions needed for mechanical resonance, and proposed measures to prevent this from occurring.
P9 Analyse the natural frequency of vibration in a mass-spring system.	**M4** Analyse the transient response within a mass-spring damper system.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Aremu B. (2023) *Introduction to Mechanical Engineering Science: A solid foundation of sound engineering principles, analysis and technical problem-solving skills* (Paperback). IngramSpark.

Bird J. and Ross C. (2020) *Mechanical Engineering Principles*. 4th Ed. London: Routledge.

Hibbeler R.C. (2023) *Mechanics of Materials*. SI Edition. 11th Ed. Pearson

Hibbeler R.C. (2020) *Engineering Mechanics: Dynamics and Statics*. SI Edition. 14th Ed. Pearson.

Moseley H. (2022) *The Mechanical Principles of Engineering and Architecture* (Paperback). Legare Street Press.

Rao S.S. (2023) *Mechanical Vibrations in SI Units*. 6th Ed. Pearson

Tooley M. and Dingle L. (2020) *Engineering Science: For Foundation Degree and Higher National*. 2nd Ed. London: Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

International Journal of Mechanical Sciences

Journal of Mechanical Engineering

Journal of Mechanical Engineering Research and Developments

Journal of Mechanical Science and Technology

Mechanical Engineering Journal

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4002: Engineering Maths

Unit 5003: Advanced Mechanical Principles.

Unit 4009: Materials, Properties and Testing

Unit Code: J/615/1483

Level: 4

Credits: 15

Introduction

The world we live in would be a very different place without the sophisticated engineering materials currently available. Many of the things we take for granted, such as telecommunications, air travel, safe and low-cost energy, or modern homes, rely on advanced materials development for their very existence. Successful engineering application and innovation is dependent upon the appropriate use of these materials, and the understanding of their properties.

This unit introduces students to the atomic structure of materials and the way it affects the properties, physical nature and performance characteristics of common engineering/manufacturing materials; how these properties are tested, and modified by various processing treatments; and problems that occur which can cause materials to fail in service.

On successful completion of this unit students will be able to explain the relationship between the atomic structure and the properties of materials, translate design requirements into materials selection strategy and determine the suitability of engineering materials for use in a specified role using industry-standard software [GRANTA Edupack], explore the testing techniques to determine the properties of engineering materials and identify the causes of in-service material failure.

Learning Outcomes

LO1 Explain the relationship between the atomic structure and the properties of materials

LO2 Determine the suitability of engineering materials satisfying functional, environmental and sustainability requirements for use in a specified role

LO3 Analyse the testing techniques to determine the mechanical properties of an engineering material

LO4 Investigate the causes of in-service material failure.

Essential Content

LO1 **Explain the relationship between the atomic structure and the properties of materials**

Properties of materials:

Classification and terminology of engineering materials

Material categories: metallic, ceramic, polymer and composites

Atomic structure: metallic, covalent and ionic bonding

Crystalline structures: body-centred and face-centred cubic lattice and hexagonal close-packed

Characteristics and function of ferrous and non-ferrous phase diagrams

Structure of polymers and properties: polymerization, polyaddition, polycondensation, amorphous and crystalline polymer structures

Linear and branched polymers: atactic, isotactic, syndiotactic structures.

LO2 **Determine the suitability of engineering materials satisfying functional, environmental and sustainability requirements for use in a specified role**

Materials used in specific roles:

The relationship between product design requirements and material selection strategy

Categorising materials by their chemical, physical, mechanical, electrical and thermal properties

The effect heat treatment and mechanical processes have on material properties

How environmental/sustainability factors can affect the material behaviour of metallic, ceramic, polymer and composite materials

Consideration of the impact that forms of supply and cost have on material selection

Hazardous engineering materials, contamination issues and society wellbeing

The application of the circular economy concept in selecting a material for a specified role.

LO3 **Analyse the testing techniques to determine the mechanical properties of an engineering material**

Testing techniques:

Destructive and non-destructive tests used to identify material properties

The influence of test results on material selection for a given application

Most appropriate tests for the different categories of materials

Undertaking mechanical tests on each of the four material categories for data comparison and comparing results against industry-recognised data sources, explain reasons for any deviation found.

LO4 **Investigate the causes of in-service material failure.**

Material failure:

Reasons why engineered components fail in service

Categories of material failures

Working and environmental conditions that lead to material failure

Common mechanisms of failure for metals, polymers, ceramics and composites

Example failure mechanisms (e.g., overload, fatigue, stress corrosion cracking, delayed hydrogen cracking, creep) and industry case studies

Preventative measures that can be used to extend service life.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the relationship between the atomic structure and the different properties of materials		
P1 Discuss, with example, the three crystal structures often found in metals. **P2** Explain the different material properties that are associated with amorphous and crystalline polymer structures.	**M1** Describe physical, mechanical, electrical and thermal material properties, choosing practical applications for each property if it were to be used in an engineering context.	**D1** Evaluate how the composition and structure of materials influence the properties of the parent material across the material's range.
LO2 Determine the suitability of engineering materials satisfying functional, environmental and sustainability requirements for use in a specified role		
P3 Provide a list of the four materials categories, including an example of a product and application for each material identified. **P4** Determine the specific characteristics related to the behaviour of the four categories of engineering materials.	**M2** Explain how the behaviour of materials and circular economy needs to be considered when selecting a material for a given product or application. **M3** Analyse, with examples, the effect heat treatment and mechanical processes have on material properties.	**D2** Describe, with example, how to translate a product design specification into a material selection strategy and drive materials indices and select possible materials using the GRANTA Edu pack.
LO3 Analyse the testing techniques to determine the mechanical properties of an engineering material		
P5 Analyse the results of mechanical test(s) on each of the four material categories in the form of a report.	**M4** Compare results against industry-recognised data sources, explaining any difference found.	**D3** Critically evaluate sources of error in the mechanical test and make recommendations for better data collection.
LO4 Investigate the causes of in-service material failure.		
P6 Describe six common mechanisms of failure. **P7** Investigate working and environmental conditions that lead to failure for a product made from material from each of the four material categories.	**M5** Explain, with examples, the preventative measures that can be used to extend the service life of a given product within its working environment.	**D4** Justify the methods that could be used for estimating product service life when a product is subject to creep and fatigue loading.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby M. F. (2016) *Materials Selection in Mechanical Design*. 5th Ed. Butterworth-Heinemann.

Ashby M.F. and Jones D. R. (2018) *Engineering materials 1: An Introduction to Properties, Applications, and Design.* 5th Ed. Butterworth − Heinemann.

Balkose D., Horak D. and Soltes L. (2021) *Key Engineering Materials, Volume 1 – Current State-of-the-Art on Novel Materials*. Apple Academic Press.

Baur E., Osswald T.A., and Rudolph N. (2019) *Plastics Handbook − The Resource for Plastics Engineers.* 5th Ed. Hanser Publishers.

Callister W.D. and Rethwisch G.D. (2020) *Materials science and engineering:an introduction.* 10th Ed. Wiley.

Chowdhury M.A. (Editor) (2021) *Composite Materials*. IntechOpen. Online edition.

Crawford R.J. and Martin P.J. (2019) *Plastics Engineering*. 4th Ed. Butterworth-Heinemann.

Gay D. (2015) *Composite materials: design and applications*. 3rd Ed. CRC Press, Taylor & Francis.

Gloag J. (2022) Plastics and Industrial Design. Routledge.

Grellmann W., Seidler S., and Anderson P.I. (2023) *Polymer Testing.* 3rd Ed. Elsevier.

Gupta K.M. (2020) *Engineering Materials – Research, Applications and Advances.* CRC Press.

Lynch C.T. (2023) *Handbook of Materials Science Volume 1 General Properties.* CRC Press.

Mcevily A. J., Kasivitamnuay J. (2013) *Metal Failures: Mechanisms, Analysis, Prevention*. Wiley.

Rosato D.V. (2003) *Plastics Engineered Product Design.* 1st Ed. Elsevier Illustrated edition.

Srivatsan T.S., Sudarshan T.S., and Manigandhan K. (2020) *Manufacturing Techniques for Materials – Engineering and Engineered*. CRC Press.

Vakhrushev A.V. and Haghi A.K. (2021) *Composite Materials Engineering – Modelling and Technology.* Apple Academic Press.

Verma C., Aslam R. and Aslam J. (2023) *Grafted Biopolymers as Corrosion Inhibitors.* Wiley.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

ACS Applied Engineering Materials

Advanced Engineering Materials

Composites Part B: Engineering

International journal of Refractory Metals and Hard Materials

Journal of Engineering Materials and Technology

Journal of Materials Processing Technology

Material Science: Science Direct

Material Science and Engineering

Materials & Design

Materials Testing

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4010: Mechanical Workshop Practices.

Unit 4010: Mechanical Workshop Practices

Unit Code: M/651/0722

Level: 4

Credits: 15

Introduction

The complex and sophisticated engineering manufacturing processes used to mass produce the products we see and use daily has its roots in the hand-operated lathes and milling machines still used in small engineering companies. To appreciate the fundamentals underpinning complex manufacturing processes, it is essential that engineers are able to read engineering drawings and produce simple components accurately and efficiently.

This unit introduces students to the effective use of textual, numeric and graphical information, how best to extract and interpret information from engineering drawings, and the practices of workshop-based turning and milling machining.

On successful completion of this unit students will be able to learn about the mechanical measurement and quality control processes to analyse the dimensional accuracy of a machined component; operating machining equipment to produce a range of components to specification; the importance of material selection when choosing the most appropriate machining process; and application of safe working practices throughout.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Discuss the potential hazards that exist when operating machine tools and bench fitting equipment, with reference to the appropriate health and safety regulations and risk assessment criteria

LO2 Produce dimensionally accurate engineering components through operating a manual lathe and milling machine

LO3 Interpret information from engineering drawings to operate measuring tools and work-holding equipment to check dimensional accuracy of machined components

LO4 Explain mechanical measurement and quality control processes.

Essential Content

LO1 **Discuss the potential hazards that exist when operating machine tools and bench fitting equipment, with reference to the appropriate health and safety regulations and risk assessment criteria**

Safety compliance:

Importance of, and responsibility for, safe working practice

Safe working practices when operating machining equipment in the mechanical machine workshop

Safe working practices when performing workshop fitting activities, e.g. using hand tools for marking out, sawing, filing, drilling, tapping and assembling parts

Consider the implications of waste produced by the workshop process, relating to environmental and health and safety issues

Workshop safety legislation and regulations, and how they are met in practice

Risk assessment of bench fitting and machining activities

Discuss in groups a range of industry case studies involving hazards and mitigation measures undertaken.

LO2 **Produce dimensionally accurate engineering components through operating a manual lathe and milling machine**

Operation:

Factors influencing machining operations

Set-up and use of a manual lathe and milling machine following all safety procedures

Most appropriate cutting tools, work and tool holding methods for multiple applications

Speeds and feeds to suit material properties (e.g., metallics, non-metallics/composites/plastics) and application

Use of work-holding jigs and fixtures

Removing material within dimensional tolerances.

LO3 **Interpret information from engineering drawings to operate measuring tools and work-holding equipment to check dimensional accuracy of machined components**

Drawings function:

Types of engineering drawing and their use

Developing proficiency in reading and extracting information from mechanical engineering drawings

Types of measuring tools

Characteristics of measurement tools for inspecting parts

Preparing quality control and inspection reports.

LO4 **Explain mechanical measurement and quality control processes**

Control processes:

Types of production quality control processes, metrology techniques

Importance of quality checks on machined components

Function of quality control metrology equipment, including CNC controlled coordinate measuring machines, mobile measuring arms and touch probes, contact scanning probes and non-contact sensors (optical)

Importance of the process for data collection, analysis and product improvement.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss the potential hazards that exist when operating machine tools and bench fitting equipment, with reference to the appropriate health and safety regulations and risk assessment criteria		
P1 Discuss a range of possible hazards associated with operating machine tools and bench fitting equipment. **P2** Explain the safe working practices and procedures to be followed when preparing and using a manual lathe and milling machine.	**M1** Produce a risk assessment, identifying suitable control measures, prior to undertaking a machining activity.	**D1** Interpret the key features of relevant health and safety regulations as applied to machine tools and bench fitting equipment in a machining workshop.
LO2 Produce dimensionally accurate engineering components through operating a manual lathe and milling machine		
P3 Produce a dimensionally accurate component using a lathe and milling machine.	**M2** Calculate appropriate cutting speeds and feeds to suit the material properties and application for the component.	**D2** Evaluate the operating parameters of the milling machine and lathe and the function and features of the associated cutting tools, work and tool-holding devices.

Pass	Merit	Distinction
LO3 Interpret information from engineering drawings to operate measuring tools and work-holding equipment to check dimensional accuracy of machined components		
P4 Interpret information from an engineering drawing to plan, machine and check the accuracy of a complex component. **P5** Explain the function of precision measuring equipment used to check the dimensional accuracy of a machined component.	**M3** Analyse the function of the tooling/equipment required to machine and measure components made from aluminium alloy, stainless steel and titanium alloy.	**D3** Evaluate, with reference to material properties and geometry, the criteria for the selection of the appropriate tooling for machining components from engineering materials including aluminium alloy, stainless steel and titanium alloy.
LO4 Explain mechanical measurement and quality control processes		
P6 Explain the purpose of an engineering metrology laboratory with a list of equipment found in a typical metrology laboratory	**M4** Analyse the function of the metrology equipment, surface testing, profile projectors, video measuring, interferometer, SIP measuring equipment, coordinate measuring machines (CMM) and 3D scanners	**D4** Evaluate why accurate measurement and the process of machining data collection and analysis are of critical importance to a production engineering company

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Black B.J. (2015) *Workshop Processes, Practices and Materials*. Routledge.

Harrison D. (2022) *Workshop Machining: A Comprehensive Guide to Manual Operation*. 1st Ed. Routledge.

John K.C. (2010) *Mechanical Workshop Practice*. 2nd Ed. Prentice-Hall.

Pfeifer T. (2015) *Production Metrology*. Berlin: De Gruyter.

Raghavendra N.V. and Krishnamurthy L. (2013) *Engineering Metrology and Measurements*. Oxford University Press.

Sawhney G.S. (2013) *Mechanical Experiments and Workshop Practice (Paperback).* I K International Publishing House Pvt. Ltd.

Syam D.J. (2023) *Mechanical Engineering Practices in Industry: A Beginner's Guide*. 1st Ed. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Engineering

International Journal of Metrology and Quality Engineering

Journal of King Saud University – Engineering Sciences

Measurement

Metrology Journal, MDPI

Precision Engineering

Links

This unit links to the following related units:

Unit 4009: Materials, Properties and Testing

Unit 4014: Production Engineering for Manufacture.

Unit 4011: Fluid Mechanics

Unit Code: T/651/0724

Level: 4

Credits: 15

Introduction

Fluid mechanics is an important subject to scientists and engineers of many disciplines, not just those working directly with fluid systems. Mechanical engineers need to understand the principles of hydraulic devices and turbines (wind and water); aeronautical engineers use these concepts to understand flight and design flying machines, while civil engineers typically concentrate on water supply, sewerage, and irrigation.

This unit introduces students to the fluid mechanics principles and techniques used in mechanical engineering. In particular, the hydraulic devices and systems that incorporate the transmission of hydraulic pressure and forces exerted by a static fluid on immersed surfaces.

Topics included in this unit are: pressure and force, submerged surfaces, fluid flow theory, aerodynamics, and hydraulic machinery.

On successful completion of this unit students will be able to learn about the concept and measurement of viscosity in fluids, and the characteristics of Newtonian and non-Newtonian fluids; fluid flow phenomena, including energy conservation, estimation of head loss in pipes and viscous drag; and the operational characteristics of hydraulic machines, in particular the operating principles of various water turbines and pumps.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine the behavioural characteristics of static fluid systems

LO2 Examine the operating principles and limitations of viscosity measuring devices

LO3 Investigate dynamic fluid parameters of real fluid flow

LO4 Explore the operating principles and efficiencies of hydraulic machines.

Essential Content

LO1 **Determine the behavioural characteristics of static fluid systems**

Pressure and force:

How Pascal's laws define hydrostatic pressure

Pressure with the use of manometers

Transmission of force in hydraulic systems and devices.

Submerged surfaces:

Determining thrust on immersed surfaces

Moments of area and parallel axis theorem

Calculating centre of pressure with moments of area.

LO2 **Examine the operating principles and limitations of viscosity measuring devices**

Viscosity in fluids:

Dimensional analysis (the Buckingham π theorem)

Dynamic and kinematic viscosity definitions

Characteristics of Newtonian fluids

Effects of temperature on viscosity

Classification of non-Newtonian fluids.

Operating principles and limitations:

Operating principles of viscometers

Rheometers for Non Newtonian fluids

Converting results acquired from viscometers into viscosity values.

LO3 **Investigate dynamic fluid parameters of real fluid flow**

Fluid flow theory:

Energy present within a flowing fluid and the formulation of Bernoulli's Equation

Classification of fluid flow using Reynolds numbers

Calculations of flow within pipelines

Head losses that occur within a fluid flowing in a pipeline

Viscous drag resulting from fluid flow and the formulation of the drag equation.

Aerodynamics:

Application of prior theory of fluid flow to aerodynamics

Principles of aerofoils and lift-induced drag

Flow measuring devices and their operating principles.

LO4 **Explore the operating principles and efficiencies of hydraulic machines**

Hydraulic machinery:

Operating principles of different types of water turbine

Reciprocating and centrifugal pump theory

Efficiencies of different types of hydraulic machinery

Environmental concerns surrounding hydraulic machines.

Use of relevant problem-solving tools within the context of a chosen scenario/sector e.g. root cause analysis (RCA), process failure modes effects analysis (PFMEA), fishbone, practical problem solving (PPS) and advanced product quality planning (APQP).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine the behavioural characteristics of static fluid systems		
P1 Determine force and centre of pressure on submerged surfaces. **P2** Examine the parameters of hydraulic devices that are used in the transmission of force.	**M1** Carry out appropriate calculations on force and centre of pressure on submerged surfaces.	**D1** Explain the use and limitations of manometers to measure pressure.
LO2 Examine the operating principles and limitations of viscosity measuring devices		
P3 Examine the operation and constraints of different viscometers that quantify viscosity in fluids. **P4** Carry out appropriate calculations on the effect of changes in temperature and other constraints on the viscosity of a fluid.	**M2** Explain, with examples, the effects of temperature and shear forces on Newtonian and non-Newtonian fluids.	**D2** Illustrate the results of a viscosity test on a Newtonian fluid at various temperatures with those given on a data sheet and explain discrepancies.
LO3 Investigate dynamic fluid parameters of real fluid flow		
P5 Determine parameters of a flowing fluid using Bernoulli's Equation. **P6** Investigate the flow of a fluid using Reynold's numbers and the significance of this information.	**M3** Explain the effect of aerodynamic drag and lift on aerofoils.	**D3** Analyse the head losses accumulated by a fluid when flowing in a pipeline for various applications.
LO4 Explore the operating principles and efficiencies of hydraulic machines		
P7 Determine the efficiency of a water turbine. **P8** Calculate the input power requirements of centrifugal pumps. **P9** Explore operating efficiencies and applications of two different hydraulic machines.	**M4** Analyse the limitations that exist within different types of water turbine.	**D4** Critically analyse the arguments concerning the ecological impact of hydroelectric power.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Cengel Y.A. and Cimbala J.M. (2018) *Fluid Mechanics: Fundamentals and Applications.* 4th Ed: McGraw-Hill Education

Elger D.F., Williams B.C. and Crowe C.T. (2022) Engineering fluid mechanics. John Wiley & Sons.

Han J. and wright L. (2020) *Experimental Methods in Heat Transfer and Fluid Mechanics.* 1st Edition. CRC Press.

Hibbeler R.C. (2020) *Fluid Mechanics in SI Units.* 2nd edition. Pearson.

Mott R.L. and Untener A. (2023) *Applied Fluid Mechanics, Global Edition.* 7th edition. Pearson.

Rathakrishnan E. (2022) *Encyclopaedia of Fluid Mechanics.* 1st Edition. CRC Press.

Rathakrishnan E. (2022) *Fluid mechanics: An introduction.* PHI Learning Pvt. Ltd.

Rodrigues J.F. and Sequeira A. (2020) *Mathematical Topics in Fluid Mechanics.* CRC Press.

Shivamoggi B.K. (2022) *Introduction to Theoretical and Mathematical Fluid Dynamics.* Wiley.

Uddin N. (2023) *Fluid Mechanics: A Problem-Solving Approach.* 1st Edition. CRC Press.

White F. and Xue H. (2020) *Fluid Mechanics.* 9th Edition. McGraw-Hill.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Annual Review of Fluid Mechanics

Experiments in Fluids

Fluid Dynamics

Journal of Applied Fluid Mechanics

Journal of Fluid Mechanics

Links

This unit links to the following related units:

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit 5023: Thermofluids.

Unit 4012: Engineering Management

Unit Code: A/651/0726

Level: 4

Credits: 15

Introduction

Managing engineering projects is one of the most complex tasks in engineering. Consider the mass production of millions of cars, sending a man or women into space or extracting oil or gas from deep below the surface of the earth. Bringing the materials and skills together in a cost effective, safe and timely way is what engineering management is all about.

This unit introduces students to engineering management principles and practices, and their strategic implementation.

Topics included in this unit are: the main concepts and theories of management and leadership, fundamentals of risk management, operational management, project and operations management theories and tools, the key success measures of management strategies, and planning tools.

On successful completion of this unit students will be able to investigate key strategic issues involved in developing and implementing engineering projects and solutions, and explain professional codes of conduct and the relevant legal requirements governing engineering activities.

Learning Outcomes

LO1 Examine the application of management techniques, and cultural and leadership aspects to engineering organisations

LO2 Explore the role of risk and quality management in improving performance in engineering organisations

LO3 Investigate the theories and tools of project and operations management when managing activities and optimising resource allocation

LO4 Perform activities that improve current management strategies within an identified element of an engineering organisation.

Essential Content

LO1 **Examine the application of management techniques, and cultural and leadership aspects to engineering organisations**

Main concepts and theories of management and leadership:

Influence on organisational culture and communication practices

Effect of change within an organisation on its culture and behaviour.

Management and leadership theories:

Management and leadership theories

Managerial behaviour and effectiveness

Organisational culture and change

Organisational communication practices.

LO2 **Explore the role of risk and quality management in improving performance in engineering organisations**

Fundamentals of quality management:

Introduction to monitoring and controlling

Most appropriate quality improvement methodologies and practices for different business areas, projects and processes in order to lower risk and improve processes.

Risk and quality management:

Risk management processes

Risk mapping and risk matrix

Quality management theories

Continuous improvement practices

Principles, tools and techniques of Total Quality Management (TQM).

LO3 **Investigate the theories and tools of project and operations management when managing activities and optimising resource allocation**

Operation management:

Main areas and stages of projects and operations management

Most important methodologies focusing on eliminating waste and smoothing the process flows without scarifying quality.

Project and operations management theories and tools:

Project appraisal and life cycle

Logistics and supply chain management

Operations management

Resources management

Sustainability

Legal requirements governing employment, health, safety and environment.

LO4 **Perform activities that improve current management strategies within an identified element of an engineering organisation.**

The key success of management strategies:

Following processes from end to end, from suppliers to customers

Identifying areas critical for the success of a project or process.

Planning tools:

Gantt charts

Flow charts

Critical analysis and evaluation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the application of management techniques, and cultural and leadership aspects to engineering organisations		
P1 Explain management and leadership theories and techniques used within engineering organisations.	**M1** Justify different management techniques with emphasis on cultural and leadership aspects and their applications to engineering organisations.	**D1** Propose recommendations for the most efficient application of management techniques.
LO2 Explore the role of risk and quality management in improving performance in engineering organisations		
P2 Describe the role and importance of risk and quality management processes and their impact on engineering organisations.	**M2** Explain how risk and quality management strategies encourage performance improvements within engineering organisations.	**D2** Provide supported and justified recommendations for the most efficient and effective risk and quality management practices.
LO3 Investigate the theories and tools of project and operations management when managing activities and optimising resource allocation		
P3 Identify project and operations management tools used when managing activities and resources within the engineering industry.	**M3** Analyse the most effective project and operations management tools used when managing activities and optimising resource allocation.	**D3** Analyse the relative merits of theories and tools of project and operations management, with a focus on their relevance when managing activities and optimising resource allocation.
LO4 Perform activities that improve current management strategies within an identified element of an engineering organisation.		
P4 Define the range of processes available to improve management processes within an engineering organisation.	**M4** Explore activities that will improve management strategies within an engineering organisation.	**D4** Conduct a full analysis of the management processes within an engineering organisation (or case study) and make fully justified recommendations for improvements to the management strategies.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bowersox, D.J., Closs, D., Bowersox, J.C. and Cooper, M.B (2023) *Supply Chain Logistics Management*. 6th Ed. New York: McGraw-Hill Education.

Buchanan A. D., (2019) *Organizational behaviour.* 10th Ed. Pearson.

Burke R. (2013) *Project management: planning and control techniques*. 5th Ed. Wiley.

Chapman C. and Ward S. (2003) *Project Risk Management: Processes, Techniques and Insights*. 2nd Ed. Wiley.

Hill, A. and Hill, T. (2009) *Manufacturing Operations Strategy: Texts and Cases*. 3rd Ed. Basingstoke: Palgrave Macmillan.

Meredith J.R., Shafer S., Mantel Jr S.J. and Sutton M. M. (2020) *Project Management in Practice.* 7th Ed. Wiley.

Oakland, J.S. (2015) *Statistical Process Control*. 6th Ed. London: Routledge.

Websites

http://strategicmanagement.net/	Strategic Management Society (General reference)
http://www.journals.elsevier.com/	Elsevier Journal of Operations Management (Journal)
http://www.emeraldgrouppublishing.com	Emerald Publishing International Journal of Operations & Production Management (E-journal)

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 5002: Professional Engineering Management.

Unit 4013: Fundamentals of Thermodynamics and Heat Transfer

Unit Code: D/651/0727

Level: 4

Credits: 15

Introduction

Thermodynamics is one of the most common applications of science in our lives, and it is so much a part of our daily life that it is often taken for granted. For example, when driving your car, the chemical energy from the fuel or electrical energy from the batteries are converted into mechanical energy to propel the vehicle, and the heat produced by burning gas when cooking will produce steam which can lift the lid of the pan. These are examples of thermodynamics, which is the study of the dynamics and behaviour of energy and its manifestations.

This unit introduces students to the principles and concepts of thermodynamics and its application in modern engineering.

On successful completion of this unit students will be able to learn about fundamental thermodynamic systems and their properties, the steady flow energy equation to plant equipment, principles of heat transfer to industrial applications, and the performance of internal combustion engines.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate fundamental thermodynamic systems and their properties

LO2 Apply the Steady Flow Energy Equation for analysis of thermodynamic systems

LO3 Determine the performance of heat engines

LO4 Examine the principles of heat transfer applied to industrial applications.

Essential Content

LO1 **Investigate fundamental thermodynamic systems and their properties**

Fundamental systems:

Application Areas of Thermodynamics

Forms of energy and basic definitions

Energy, Work and Power

Thermodynamic state and equilibrium

Definitions of systems (open and closed) and surroundings

Properties of pure substances and property tables.

First law of thermodynamics

The gas laws: Charles' Law, Boyle's Law, general gas law and the Characteristic Gas Equation.

The importance and applications of pressure/volume diagrams and the concept of work done

Polytrophic processes: constant pressure, constant volume, adiabatic, isothermal and isentropic process.

LO2 **Apply the Steady Flow Energy Equation for analysis of thermodynamic systems**

Energy equations:

Conventions used when describing the behaviour of heat and work

The Non-Flow Energy Equation as it applies to closed systems

Assumptions, applications and examples of practical systems

Steady Flow Energy Equation as applied to open systems

Assumptions made about the conditions around, energy transfer and the calculations for specific plant equipment e.g., boilers, super-heaters, turbines, pumps and condensers

LO3 **Determine the performance of heat engines**

Performance:

Application of the second law of thermodynamics to heat engines, heat pumps and Refrigerators.

Reversible and Irreversible Processes

Comparison of theoretical and practical heat engine cycles, including Otto, Diesel and Carnot

Explanations of practical applications of heat engine cycles, such as compression ignition (CI) and spark ignition (SI) engines with alternative fuels such as biofuels, hydrogen and ammonia, including their relative mechanical and thermodynamic efficiencies

Describe possible efficiency improvements to heat engines.

LO4 **Examine the principles of heat transfer applied to industrial applications**

Principles of heat transfer:

Modes of heat transfer: conduction, convection and radiation

Heat conduction in plane walls and thermal resistance concept

Heat transfer through composite walls and use of U and k values

Heat losses in thick and thin walled pipes, optimum lagging thickness

Application of heat transfer to different types of heat exchangers, including recuperator and evaporative

Regenerators

Safety first culture: health and safety policies, procedures and regulations; compliance; risk assessment process and procedures and mitigation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate fundamental thermodynamic systems and their properties		
P1 Investigate the operation of thermodynamic systems identifying its boundaries and surroundings. **P2** Explain the application of the first law of thermodynamics to appropriate systems. **P3** Explain the relationships between system constants for a perfect gas.	**M1** Investigate the index of compression in polytrophic processes.	**D1** Apply the first law principles to derive the work and heat transfer for thermodynamic processes of perfect gas.
LO2 Apply the Steady Flow Energy Equation for analysis of thermodynamic systems		
P4 Explain system parameters using the Non-Flow Energy Equation. **P5** Apply the Steady Flow Energy Equation to plant equipment.	**M2** Apply Steady Flow Energy Equations for analysis of open systems.	**D2** Evaluate application of Steady Flow Energy Equation for analysis of complex open systems.
LO3 Determine the performance of heat engines		
P6 Describe with the aid of a PV (pressure volume) the principals of Carnot or Otto or Diesel cycles based on the air-standard assumptions. **P7** Determine the maximum efficiency of heat engine or heat pump or refrigerators.	**M3** Analyse the operating condition of Carnot heat engine/heat pumps with the efficiency.	**D3** Calculate the working fluid properties in an ideal Otto/Diesel cycle and the cycle efficiency.
LO4 Examine the principles of heat transfer applied to industrial applications		
P8 Examine the principles of heat transfer through composite walls. **P9** Apply heat transfer formulae to heat exchangers.	**M4** Explore heat losses through lagged and unlagged pipes.	**D4** Distinguish the differences between parallel and counter flow recuperator heat exchangers and their heat transfer efficiencies

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ansermet J.P. and Brechet S.D. (2019) *Principles of Thermodynamics* Hardcover. Cambridge University Press.

Assael M.J., Maitland G.C., Maskow T., Von Stockar U., Wakeham W.A. and Will S. (2022) *Commonly asked questions in thermodynamics*. CRC Press.

Borgnakke C. and Sonntag R. (2022) *Fundamental of Thermodynamics*. 10th Ed. Wiley

Cengel Y. (2019) *Thermodynamics: An Engineering Approach SI*, 9th Ed. McGraw Hill.

Cengel Y. (2020) *Heat and Mass Transfer: Fundamentals and Applications*, 6th Ed. McGraw Hill.

Desmet B. (2022) *Thermodynamics of Heat Engines*. Wiley.

Heywood J. (2018) *Internal combustion engine fundamentals*. McGraw-Hill.

Holman J. (2009) *Heat Transfer*. McGraw- Hill.

Lee J.H. and Ramamurthi K. (2022) *Fundamentals of thermodynamics*. CRC Press.

Lewis G.N., Randall M., Pitzer K.S. and Brewer L. (2020) *Thermodynamics*. Courier Dover Publications.

Packer N. and Al-Shemmeri T. (2018) *Conventional and Alternative Power Generation: Thermodynamics, Mitigation and Sustainability*. Wiley.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Applied Thermal Engineering

International Communications in Heat and Mass Transfer

International Journal of Heat and Mass Transfer

International Journal of Thermal Sciences

Journal of Turbomachinery

Links

This unit links to the following related units:

Unit 5005: Further Thermodynamics.

Unit 4014: Production Engineering for Manufacture

Unit Code: H/651/0729

Level: 4

Credits: 15

Introduction

All of the manufactured products we use in our daily lives, from processed food to clothing and cars, are the result of production engineering. Production engineers need to have a comprehensive knowledge and understanding of all the possible production technologies available, their advantages and disadvantages, the requirements of the production system operation and the interaction between the various components of the production system.

This unit introduces students to the production process for key material types; the various types of machinery used to manufacture products and the different ways of organising production systems to optimise the production process; consideration of how to measure the effectiveness of a production system within the overall context of the manufacturing system; and an examination of how production engineering contributes to ensuring safe and reliable operation of manufacturing.

On successful completion of this unit students will be able to learn about the role and purpose of production engineering and its relationship with the other elements of a manufacturing system; most appropriate production processes and associated facility arrangements for manufacturing products of different material types; and designing a production system incorporating a number of different production processes.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system

LO2 Describe the most appropriate production processes and associated facility arrangements for manufacturing products of different material types

LO3 Analyse how a production system can incorporate a number of different production processes for a given product or assembly

LO4 Explore the effectiveness of a production system in terms of its operation within the wider manufacturing system.

Essential Content

LO1 **Illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system**

Production engineering activities:

Common practices for manufacturing

Research and develop tools, processes, machines, and equipment

Integrate facilities, production layout, and systems for producing quality products

Design, implement and refine products, services, processes and systems, considering manufacture, assembly and end of life

Use financial planning, recording and review processes and documentation, budgets, estimating, cost control, cost forecasting, and investment appraisal

Application of quality system tools to support production engineering to include, Inspection strategies, Check Sheets, Fishbone Diagram, Histogram, Pareto Chart, Control Chart, Scatter Diagram and Process Flowcharts.

Combination of manufacturing technology and management science.

LO2 **Describe the most appropriate production processes and associated facility arrangements for manufacturing products of different material types**

Production processes:

Common ceramics, polymer, composite, and metals manufacturing processes

The influence of mechanical and physical properties of the materials on the production process. Bonding and jointing technologies, including welding, adhesives, fasteners, locking and retaining methods, interference fits and mechanical assemblies.

LO3 **Analyse how a production system can incorporate a number of different production processes for a given product or assembly**

Function of the range of production facilities within a manufacturing plant:

Production design for manufacture and assembly

Cellular and flexible manufacturing systems

Component production using CNC machining centres and automated production processes (single, batch, flow, mass)

Automated materials handling equipment, conveyor systems, automatic guided vehicle servicing, product assembly and production lines

Heat treatment facilities, paint and coating plants

Warehouse, stock storage equipment

The purpose, operation and effects of incorporating concepts such as lean manufacturing and just-in-time (JIT) supply to the production process

Relevant manufacturing methods used and their applications, such as machining, joining, forming, assembling, shaping, processing, printing, moulding, extruding and casting.

LO4 **Explore the effectiveness of a production system in terms of its operation within the wider manufacturing system**

Production systems:

Production performance criteria, through-put rates, yield rates, cost effectiveness, sustainability, flexibility and reliability

Optimising supply chain performance and management

Documentation control processes and procedures such as format, location, access, authorisation

Production documentation management: job cards/build records, 2D & 3D drawing/models, Bill of Materials (BOM), Cost Analysis Reports, Compliance Report, Standard Operating Instructions (SOI's), Standard Process Instructions (POI's), Engineering Query Notifications (EQN's) and Drawing Query Notifications (DQN's)

Use of Industry 4.0 tools/technologies and integration to promote effectiveness and operations (e.g. automation, robots, PLCs, digital systems and manufacturing engineering systems)

Essential collaboration between manufacturer, supplier and retailer.

Production errors and rectification:

Cost in terms of time, material waste, product recall, reputation and litigation

Production data collection, critical evaluation and analysis; effective use of data collection systems and data formats.

The human component:

Human factors. Impact of organisational, job and environment factors on individual performance, characteristics, and behaviours at workplace

Cultural openness to new ideas and continuous improvement

Technically savvy to encourage advanced/latest technologies for efficiencies including performance optimisation

Collaboration and information sharing.

Performance management and rewards

Engineer training and development practices.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system</td><td rowspan="2">D1 Analyse how the production engineer supports the development of operational strategies to achieve production and financial objectives.</td></tr>
<tr><td>P1 Illustrate multiple elements of a modern manufacturing system.

P2 Explain the role of the production engineer within a manufacturing system.</td><td>M1 Assess how the production engineer can influence the design process and refine products, services and systems, taking into account optimisation and cost effectiveness.</td></tr>
<tr><td colspan="2">LO2 Describe the most appropriate production processes and associated facility arrangements for manufacturing products of different material types</td><td rowspan="2">D2 Evaluate how the choice of bonding and jointing processes influences both the product design and the selection of the most effective production process.</td></tr>
<tr><td>P3 Examine the properties and applications of ceramic products manufactured using the sintering, hot pressing, chemical vapour deposition (CVD) and reaction bonding processes.

P4 Describe the properties and applications of composite products manufactured using manual and automated layup, filament winding, pultrusion and resin transfer moulding processes.</td><td>M2 Discuss the benefits associated with polymer manufacturing process.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Analyse how a production system can incorporate a number of different production processes for a given product or assembly		
P5 Review the type and sequence of production processes a product or component would follow from initial design through to manufacture and distribution **P6** Analyse the function of the various production processes within a modern manufacturing plant considering the benefits and drawbacks.	**M3** Explain how materials, components and sub-assembly handling and conveyance can impact on the effectiveness and efficiency of a modern manufacturing plant.	**D3** Critique the relationships of just-in-time (JIT) and lean manufacturing to total quality and world-class manufacturing and their effects on production processes for a given product or assembly.
LO4 Explore the effectiveness of a production system in terms of its operation within the wider manufacturing system		
P7 Review the type of data that would be collected and analysed to measure production performance **P8** Explore the measures that can improve production performance criteria.	**M4** Explain the immediate and long-term effects that production errors and rectification can have on a manufacturing company.	**D4** Analyse the criteria by which production performance can be measured within the wider manufacturing system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Baudin M. and Netland T. (2023) *Introduction to Manufacturing: An Industrial Engineering and Management Perspective*. 1st Ed. Routledge.

Burduk A., Batako A.D.L., Machado J., Wyczolkowski R., Dostatni E. and Rojek I. (Editors (2023) *Intelligent Systems in Production Engineering and Maintenance III − Lecture Notes in Mechanical Engineering* (Paperback). Springer.

Davim J.P. (Editor) (2016) *Design of Experiments in Production Engineering*. Springer International Publishing Switzerland.

Durakbasa N.M. and Gencyilmaz M.G. (Editors) (2021) *Digitizing Production Systems: Selected Papers from ISPR2021 − Lecture Notes in Mechanical Engineering* (Paperback). Springer.

Grote K.H. and Hefazi H. (Editors) (2021) *Springer Handbook of Mechanical Engineering*. Springer Nature.

Groover M.P. (2020) *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*. John Wiley & Sons.

Machado C. and Davim J.P. (Editors) (2022) *Green Production Engineering and Management*. 1st Ed. Woodhead Publishing.

Mair G. (2019) *Essential Manufacturing*. Wiley.

Phanden R.K., Kumar R., Pandey P.M., and Chakraborty A. (Editors) (2023) *Advances in Industrial and Production Engineering: Select Proceedings of FLAME 2022 − Lecture Notes in Mechanical Engineering* (Paperback). Springer.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advances in Production Engineering and Management

International Journal of Production Research

Journal of Industrial and Production Engineering

Management Systems in Production Engineering

Production Engineering

Links

This unit links to the following related units:

Unit 4023: Computer Aided Design and Manufacture (CAD/CAM)

Unit 5015: Manufacturing Systems Engineering.

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit Code: M/651/0731

Level: 4

Credits: 15

Introduction

The word automation was not used until the 1940s and it originated in the automotive manufacturing sector as a method designed to reduce labour costs and improve the quality, accuracy and precision of the finished products. We are all now very familiar with the sight of dancing robots, not only in the production of cars but in everything from washing machines to pharmaceuticals. As a result of this technology the products we purchase may have never been touched by human hands and we all benefit from a reduction in costs and improvement in quality.

The aim of this unit is for students to investigate how Programmable Logic Controllers (PLCs) and industrial robots can be programmed to successfully implement automated engineering solutions.

Among the topics included in this unit are: PLC system operational characteristics, different types of programming languages, types of robots and cell safety features.

On successful completion of this unit students will be able to learn about programming PLCs and robotic manipulators to implement a set of activities, different types and uses of PLCs and robots available, writing PLC programs using a language of their choice, and program industrial robots with straightforward commands and safety factors.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the design and operational characteristics of a PLC system

LO2 Design a PLC program by considering function requirements, PLC information, programming and communication techniques

LO3 Program industrial robots using commands to perform a given task with the knowledge of the key elements and their functions

LO4 Investigate the design and safe operation of a robot within an industrial application.

Essential Content

LO1 **Describe the design and operational characteristics of a PLC system**

System operational characteristics:

Modular, unitary and rack mounted systems

Characteristics, including speed, memory, scan time, voltage and current limits

Input and output devices (digital, analogue)

Interface requirements

Communication standards (RS-232, RS-422, RS-485, Ethernet)

Industrial communication networks at Supervisory (e.g. Ethernet), Cell (e.g. PROFINET/PROFIBUS) and Field (e.g. AS-Interface) levels; industrial networks configuration and commissioning; installation, application and operational aspects

Industrial Communication Protocols (e.g., Profinet, EtherNet/IP, Powerlink)

Internal architecture

Different types of programming languages (IEC 61131-3)

Programmable Logic Controllers (PLC), Variable Speed Drives (VSD), Human Machine Interface (HMI) and Supervisory Control and Data Acquisition (SCADA).

LO2 **Design a PLC program by considering function requirements, PLC information, programming and communication techniques**

Programming language:

Signal types

Number systems (binary, octal, hexadecimal)

Allocation lists of inputs and outputs

Communication techniques

Network methods

Logic functions (AND, OR, XOR)

Associated elements (timers, counters, latches)

PLC, HMI & SCADA configuration, and programming

Modern context of PLC programming and Automation

Test and debug methods:

Systematic testing and debugging methods

Proper application of appropriate testing and debugging methods

LO3 **Program industrial robots using commands to perform a given task with the knowledge of the key elements and their functions**

Element considerations:

Types of robots

Mobile robotics

Sensors, tools and end effectors

Programming methods

Key functions/commands and application in designing and implementing robot tasks

Robotics hardware and software tools, configuration, calibration, programming, and fault finding

Robot manipulators (kinematics, design, dynamics and control, vision systems, user interfaces, instrumentation configuration and calibration); effective use of data collection tools/systems and data formats for inputs/outputs within the context.

Impact of Industry 4.0:

Automation, robots, PLCs, smart factories using Industry 4.0 based technologies (e.g., data and digital technologies/systems)

Performance optimisation

Documentation control processes and procedures such as format, location, access, authorisation

Integration and impact on organisations.

LO4 **Investigate the design and safe operation of a robot within an industrial application**

Safety:

Health and safety policies, procedures and regulations, potential hazards, risk assessment and mitigation

Cell safety features

Operating envelope

Operational modes

User interfaces

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the design and operational characteristics of a PLC system		**D1** Analyse the internal architecture of a typical PLC to determine its operational applications.
P1 Describe the key differences of PLC types and configurations, and their typical applications. **P2** Determine the types of PLC input and output devices available. **P3** Describe the different types of communication links used with PLCs.	**M1** Explain the different types of PLC programming languages available.	
LO2 Design a PLC program by considering function requirements, PLC information, programming and communication techniques		**D2** Create a fully functional PLC design for a given industrial task, with performance analysis.
P4 Design key elements that have to be considered in the preparation of a PLC program. **P5** Explain how communication connections are correctly used with the PLC.	**M2** Integrate methods used for testing and debugging PLC hardware and software.	
LO3 Program industrial robots using commands to perform a given task with the knowledge of the key elements and their functions		**D3** Produce a fully working robotic program for a given industry task, with an illustrated scope for further improvements to achieve complex tasks.
P6 Using a selection of commands, program an industrial robot to perform given task. **P7** Explain the types of robot tools, sensors, and end effectors available and their applications.	**M3** Investigate a given industrial robotic system and make recommendations for improvement.	
LO4 Investigate the design and safe operation of a robot within an industrial application		**D4** Design a safe working plan for an industrial robotic cell in a given production process, including a full risk assessment.
P8 Investigate the safety systems used within an industrial robotic cell.	**M4** Analyse how the systems in place ensure safe operation of a given industrial robotic cell.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Auat F., Prieto P. and Fantoni G. (Editors) (2022) *Rapid Roboting: Recent Advances on 3D Printers and Robotics − Intelligent Systems, Control and Automation: Science and Engineering 82* (Hardback). Springer.

Bolton W. (2015) *Programmable Logic Controllers*. 6th Ed. Elsevier.

Bozek P., Krenický T. and Nikitin Y. (Editors) (2022) *Automation and Robotics: Latest Achievements, Challenges and Prospects* (Hardback). Mdpi AG.

Dawkins N. (ed.) (2014) *Automation and Controls: A guide to Automation, Controls, PLCs and PLC Programming*.

Johnson Jr C.H. and Sanusi A.L. (2022) *PLC Programming from Novice to Professional: Learn PLC Programming with Training Videos (Paperback). Ojula Technology Innovations*.

Kumar K. and Babu B.S. (Editors) (2023*) Industrial Automation and Robotics − Techniques and Applications*. 1st Ed. CRC Press.

Manesis S. and Nikolakopoulos G. (2018) *Introduction to Industrial Automation.* 1st Ed. Routledge, Taylor and Francis Group.

Perez A. E. (2012) *Introduction to PLCs: A beginner's guide to Programmable Logic Controllers*.

Petruzella F. (2023) *Programmable Logic Controllers.* 6th Ed. McGraw Hill.

Stewart G.R. (2021) *Siemens Plc Programming For Beginners: (Step-by-Step Instructions) How Can I Quickly and Easily Learn PLC Programming At Home?* Independent publication.

White M.T. (2023) *Mastering PLC Programming: The software engineering survival guide to automation programming* (Paperback). Packt Publishing Limited.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Automation and Remote Control

Automation

IFAC Journal of Systems and Control

IEEE Journal on Robotics and Automation

International Journal of Automation and Control (IJAAC)

Journal of AI, Robotics and Workplace Automation

Journal of Automation and Intelligence

Programmable Logic Controllers (Special issue)

Robotics

Links

This unit links to the following related units:

Unit 4006: Mechatronics

Unit 5009: Further Programmable Logic Controllers (PLCs).

Unit 4016: Instrumentation and Control Systems

Unit Code: T/651/0733

Level: 4

Credits: 15

Introduction

Instrumentation and control can also be described as measurement automation, which is a very important area of engineering. It is responsible for the safe control of a wide range of processes from power stations to manufacturing facilities and even the cruise control in cars.

This unit introduces students to the important principles, components, and practices of instrumentation in controlling of a system, together with the terminology, techniques and components that are used in such a system.

Among the topics included in this unit are: instrumentation systems, instrumentation signal terminology, signal conversion and conditioning, process control systems, process controller terminology, system terminology and concepts, system tuning techniques and application of predicted values to a control system.

On successful completion of this unit students will be able to learn about the measurement of system parameters to a successful process control performance, when and how such measurements are carried out, and developing skills in applying predicted values in order to ensure stability within a control system for a range of input wave forms.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe operation of instrumentation devices including parameters used in process control

LO2 Investigate process control systems and controllers

LO3 Analyse the control concepts used within an industrial process

LO4 Apply predicted values to ensure stability within a control system.

Essential Content

LO1 **Describe operation of instrumentation devices including parameters used in process control**

Instrumentation systems:

Sensors and transducers used in instrumentation including resistive, inductive, capacitive, ultrasonic, pressure, semiconductor, thermocouple and optical

Investigate key design aspects of instrumentation systems using latest industry case studies.

Instrumentation signal terminology:

The importance of instrumentation signal terminology, error, drift, repeatability, including the difference between accuracy and precision, reliability, linearity, sensitivity, resolution, range, and hysteresis.

Signal conversion and conditioning:

Conversion and conditioning of signals, including analogue, digital, optical, microprocessor, wireless and industry standard signal ranges.

LO2 **Investigate process control systems and controllers**

Process control systems:

The need for process control systems, including quality, safety, consistency, optimisation, efficiency, cost and environmental considerations

Investigate key design aspects of instrumentation systems using latest industry case studies.

Process controller terminology:

Defining set point, process value, output, error, gain, deviation, range, on-off control, two step control and three term control PID (proportional, integral and derivative).

LO3 Analyse the control concepts used within an industrial process

System terminology and concepts:

Recognise system terminology and concepts, including distance velocity lags, capacity, resistance, static and dynamic gain, feedback types, open and closed loop, feed forward control and stability (underdamped, overdamped and critically damped system).

System tuning techniques:

Familiarise with system tuning techniques, including Zeigler-Nichols, continuous cycling, reaction curves, decay methods and overshoot tuning.

LO4 **Apply predicted values to ensure stability within a control system**

Predicted values:

Investigate block diagram representation of a simplified feedback system (plant and controller) and a closed-loop control system (reference input, controller, plant, feedback, error).

Investigate transfer function representation for a first and second order closed-loop system.

Apply predicted values to a given open and closed loop control system using simulation, to investigate system response to a range of input signal types, evaluate stability of the system using its key parameters (settling time, rise time, peak time, peak value, overshoot, steady state error) and propose possible improvements.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe operation of instrumentation devices including parameters used in process control		
P1 Describe operation of the key types of sensor and transducers used in process control. **P2** Define the signal terminology used in process control. **P3** Explain the different methods and standards used in signal conversion and conditioning.	**M1** Explore industrial applications for sensors and transducers. **M2** Analyse the accuracy of the sensors and transducers used in a particular application.	**D1** Critically review the industrial application of an instrumentation and control process system, using research evidence.
LO2 Investigate process control systems and controllers		
P4 Investigate the importance of process control systems. **P5** Explore the process controller terminology used in industrial applications.	**M3** Analyse a typical industrial application for a process control system.	**D2** Propose recommendations for improvements to process control systems and controllers.
LO3 Analyse the control concepts used within an industrial process		
P6 Examine the control terminology and concepts used in process control systems. **P7** Analyse system tuning methods and techniques employed to improve performance.	**M4** Analyse how the simulated control system responds to a range of signal inputs, in the context of a given industrial process.	**D3** Critically review the reasoning behind system response as different signals are applied, in the context of a given industrial process.
LO4 Apply predicted values to ensure stability within a control system		
P8 Demonstrate the correct use of an instrumentation and control virtual simulation. **P9** Apply tuning techniques in a typical industrial application using simulation.	**M5** Show how the virtual control system responds to a range of signal inputs with technical narrative.	**D4** Argue why the system responds in a certain way as the signals are applied, including stability aspects and possible improvements.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bolton W. (2021) *Instrumentation and Control Systems*. 3rd Ed. Elsevier.

Dabney J.B. and Harman T.L. (2003) *Mastering Simulink*. Prentice Hall.

Dorf R.C. and Bishop R.H. (2022) *Modern Control Systems*. 14th Ed. Pearson.

Essic J. (2018) *Hands-On Introduction to LabVIEW for Scientists and Engineers*. 4th Ed. Oxford University Press.

Iqbal K. (2020) *A First Course in Control System Design.* 2nd Ed. River Publishers.

Kondratenko Y.P, Kuntsevich V.M., Chikrii A.A. and Gubarev V.F. (2021) *Advanced Control Systems – Theory and Applications.* 1st Ed. River Publishers.

Moore H. (2019) *MATLAB for Engineers.* 5th Ed. Pearson.

Nagrath I.J. (2022) *Control Systems Engineering.* 7th Ed. New Age International Publishers.

Nise N.S. (2011) *Control Systems Engineering*. 6th Ed. John Wiley & Sons.

Sarangapani J. and Xu H. (2021) *Optimal Networked Control Systems with MATLAB.* CRC Press.

Cappelli M. (2023) *Instrumentation and Control Systems for Nuclear Power Plants*. 1st Ed. Woodhead Publishing.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

IEEE Transactions on Instrumentation and Measurement

Journal of Advanced Research in Instrumentation and Control Engineering

Journal of Control and Instrumentation

Journal of Instrumentation

Journal of Process Control

Transactions of the Institute of Measurement and Control

Links

This unit links to the following related units:

Unit 5007: Commercial Programming Software

Unit 5021: Further Control Systems Engineering.

Unit 4017: Quality and Process Improvement

Unit Code: **Y/651/0734**

Level: **4**

Credits: **15**

Introduction

Quality has always been the key to business success and survivability, but it requires organisations to allocate a lot of effort and resources to achieve it. The key to providing quality services and designing top quality products lies in the strength and effectiveness of the processes used in their development; processes which must be constantly reviewed to ensure they operate as efficiently, economically and as safely as possible.

This unit introduces students to the importance of quality assurance processes in a manufacturing or service environment and the principles and theories that underpin them. Topics included in this unit are: tools and techniques used to support quality control, attributes and variables, testing processes, costing modules, the importance of qualifying the costs related to quality, international standards for management (ISO 9000, 14000, 18000), European Foundation for Quality Management (EFQM), principles, tools and techniques of Total Quality Management (TQM) and implementation of Six Sigma.

On successful completion of this unit students will be able to illustrate the processes and applications of statistical process, explain the quality control tools used to apply costing techniques, identify the standards expected in the engineering environment to improve efficiency and examine how the concept of Total Quality Management and continuous improvement underpins modern manufacturing and service environments.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine the applications of statistical process control when applied in an industrial environment to improve efficiency

LO2 Analyse cost effective quality control tools

LO3 Determine the role of standards in improving efficiency, meeting customer requirements and opening up new opportunities for trade

LO4 Analyse the importance of Total Quality Management and continuous improvement in manufacturing and service environments.

Essential Content

LO1 **Examine the applications of statistical process control when applied in an industrial environment to improve efficiency**

Quality control:

The tools and techniques used to support quality control

Attributes and variables

Testing processes

Quality tools and techniques, including statistical process control (SPC), measurement of variables (such as dimensions, weight, signal, temperature, time,) testing (such as non-destructive and destructive).

Designing quality into new products and processes using Quality Function Deployment (QFD), and enhance quality in managing and monitoring supplier performance

Quality assurance: Principles and levels of quality assurance, systems, and operational consideration. Importance of accurate record keeping and monitoring of activities.

LO2 **Analyse cost effective quality control tools**

Quality costing:

Costing modules (including budgeting, forecasting and control of direct and indirect costs, fixed and variable costs including actual, accrued and committed costs), analysis and interpretation of data and information

The importance of qualifying the costs related to quality Documentation such as Parts Per Million (PPM) quality adherence, cost analysis and test data

How costs can be used to improve business performance including achieving sustainability objectives.

LO3 **Determine the role of standards in improving efficiency, meeting customer requirements and opening up new opportunities for trade**

Standards for efficiency:

The history of standards

The role of standards and their importance in enabling and supporting trade, business and industry; ethical usage of standards and implications

Standards for measurement

International Standards for management: purpose and internal governance arrangements to ensure compliance; relevant standards (ISO 9000, ISO 9001, ISO 14000, ISO 14001, ISO 18000, AS9100, TS16949 etc.)

European Foundation for Quality Management (EFQM) as an aid to developing strategic competitive advantage

Organisation context: Importance and use of organisations approved Standard Operating Procedures (SOP's), documentation recording systems and quality control, risk assessment, and the potential implications on safety, quality and delivery if they are not adhered to.

LO4 **Analyse the importance of Total Quality Management and continuous improvement in manufacturing and service environments**

Overview and function of quality:

The importance of quality to industry: how it underpins the ability to improve efficiency, meet customer requirements and improve competitiveness, cost of poor quality.

Principles, tools and techniques of Total Quality Management (TQM)

Advancements in TQM, KPIs and TQM.

Tools for improving quality and delivery. Advanced Product Quality Planning (APQP). Types of faults/defects recorded and analysed to improve future performance. Route Cause Analysis (RCA), Failure Mode and Effects Analysis (FMEA), Fishbone, Practical Problem Solving (PPS), Process Failure Mode and Effects Analysis (PFMEA). Tools for data collection and analysis, e.g., automatic test equipment, visual automatic inspection system, data acquisition equipment, software to analyse the data and inform operators in real time. Tools and techniques associated with lean manufacturing and process improvement such as Six Sigma, Kaizan, 8 Wastes. Workplace organisation such as 5S's (sort, set in order, shine, standardise and sustain), continuous flow, Poke Yoke (error proofing), 5 Whys (Root Cause Analysis), kanban (pull System), just-in-time (JIT), lean simulation activities, value stream mapping, total Preventive Maintenance Plan-do-check-act (PDCA), Single Minute Exchange of Die (SMED), A3 Reporting. Other lean operational and quality enhancement practices (e.g., visual management, waste reduction and shop floor problem solving).

Selecting the most appropriate tool/technique to solve a problem (including problem analysis models such as Is/Is Not).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the applications of statistical process control when applied in an industrial environment to improve efficiency		
P1 Review the tools and techniques used to support quality control. **P2** Examine the processes and applications of statistical process control in a production environment.	**M1** Explain the role and effectiveness of the quality tools and techniques used within an industrial environment.	**D1** Suggest justified recommendations for the application of statistical process control in an industrial environment to improve efficiency.
LO2 Analyse cost effective quality control tools		
P3 Analyse the effective use of quality control tools and techniques. **P4** Compare costing techniques used within industrial environments.	**M2** Determine with justification the quality control tools and techniques that could be used to improve business performance.	**D2** Develop a process for the application of an extensive range of quality control tools and techniques, with emphasis on costing.

Pass	Merit	Distinction
LO3 Determine the role of standards in improving efficiency, meeting customer requirements and opening up new opportunities for trade		
P5 Determine required standards to improve efficiency, meet customer requirements and open up new opportunities for trade.	**M3** Discuss the importance of standards applied in the engineering environment.	**D3** Illustrate a plan for the application of international standards that would improve efficiency, meet customer requirements and open up new opportunities for trade.
LO4 Analyse the importance of Total Quality Management and continuous improvement in manufacturing and service environments		
P6 Contrast the principles, tools and techniques of Total Quality Management and continuous improvement. **P7** Analyse how the concept of Total Quality Management and continuous improvement could help in delivering high quality performance within businesses.	**M4** Discuss how the appropriate application of Total Quality Management and continuous improvement in tools and techniques affect quality performance in the manufacturing and service environments.	**D4** Evaluate how the appropriate application of total quality management and continuous improvement in tools and techniques affect quality performance in the manufacturing and service environments.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Amsden R.T. (2019). *SPC simplified: Practical steps to quality*. Routledge.

Begum S., Rajendran C., Prakash Sai L., Ganesh K. and Mohapatra S. (2021) *Total Quality Management in Higher Education: Study of Engineering Institutions.* 1st Edition. Routledge India.

Cachon G. and Terwiesch C. (2023) *Operations Management.* 3rd Edition. McGraw-Hill

Cottmon R.J. (2020) *Total Engineering Quality Management.* 1st Edition. CRC Press.

Goetsch D.L. and Davis S. (2021) *Quality Management for Organizational Excellence: Introduction to Total Quality.* 9th edition. Pearson.

Lim J.S. (2020) *Quality Management in Engineering: A Scientific and Systematic Approach*. 1st Edition. CRC Press.

Mathur S. (2021*) Book Review of Total Quality Management in Education*. *Management Dynamics*.

Montgomery D.C. (2019) *Introduction to statistical quality control*. John Wiley & sons.

Stevenson W.J (2021) *Operations Management.* 14th Edition. McGraw-Hill.

Slack, N., Chambers, S. and Johnston, R. (2016) *Operations Management*. 8th Ed. Essex: Pearson Education Limited.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Journal of Quality in Maintenance Engineering

The TQM Journal

Quality Management Journal

Links

This unit links to the following related units:

Unit 5016: Lean Manufacturing

Unit 4018: Maintenance Engineering

Unit Code: D/651/0736

Level: 4

Credits: 15

Introduction

Plant and equipment are one of the biggest assets for any business, costing huge sums of money to replace when things go wrong. Without regular maintenance business owners could see an increase in costly breakdowns, often incurring downtime and significant loss of earnings. Inspection and maintenance are therefore vital to detect and prevent any potential equipment issues or faults that would prevent operation at optimum efficiency. Good maintenance proves itself on a day-to-day basis.

This unit introduces students to the importance of equipment maintenance programmes, the benefits that well-maintained equipment brings to an organisation and the risk factors it faces if maintenance programmes and processes are not considered or implemented. Topics included in this unit are: statutory regulations, organisational safety requirements, maintenance strategies, safe working and maintenance techniques.

On successful completion of this unit students will be able to learn about the importance of compliance with statutory regulations associated with asset maintenance, maintenance techniques adopted by the industry, safe working practices whilst performing maintenance tasks in an industrial environment and inspection and maintenance techniques.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Analyse the impact of relevant statutory regulations and organisational safety requirements on the industrial workplace

LO2 Differentiate between the merits and use of different types of maintenance strategies in an industrial workplace

LO3 Illustrate competence in working safely by correctly determining the hazards and risks associated with maintenance techniques

LO4 Apply effective inspection and maintenance techniques relative to a particular specialisation such as mechanical or electrical.

Essential Content

LO1 **Analyse the impact of relevant statutory regulations and organisational safety requirements on the industrial workplace**

Regional and global statutory regulations:

The responsibility of employers and employees with regard to statutory regulations in the workplace, including: HASWA 1974, MHSWR 1999, PUWER 1998, COSHH, LOLER 1998, Working at Height Regulations, Manual Handling Operations Regulations 1992, PPE at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Control of Noise, at Work Regulations 2005, RIDDOR 1995, CDM Regulations 2015, ACoP HSE Guidance Notes and Safety Signs

Case studies: Occupational Safety and Health Administration (OSHA), risk categories, risk assessment and prevention procedures and tools; country/region specific health and safety executive regulations.

Organisational safety requirements:

The responsibility of the employee with regard to organisational safety requirements such as the role of the HSE and the power of inspectors, right of inspection, improvement notices and prohibition notice

Product safety and raw materials safety requirements, Safety Data Sheet (SDS) of materials, PPE in all stages of operations to ensure safety.

LO2 **Differentiate between the merits and use of different types of maintenance strategies in an industrial workplace**

Maintenance strategies:

Definition of, and need for maintenance

Component failure, bathtub curve

Equipment design life and periodic maintenance (e.g. belt adjustment, lubrication etc)

Reactive, preventive, predictive and reliability centred maintenance

Comparison of the presented maintenance programmes – for example, Total Productive Maintenance (TPM), Condition Based Maintenance (CBM), Run-to-Failure Maintenance (RTF), Mean Time Between Failure (MTBF); compare and adapt latest advances in maintenance programmes

Creation and application of Failure Mode and Effects Analysis

Maintenance schedules and illustration diagrams/tools.

LO3 **Illustrate competence in working safely by correctly determining the hazards and risks associated with maintenance techniques**

Working safely:

Life-saving rules for employee safety, such as safety devices and guards, lock out, tag out, electrical work, arc flash, fall protection and permit required confined space working

Understanding plant layouts as part of safety training including emergency exists, workflow chart, stage-wise PPE, and human ergonomics

Development and implementation of safe schemes of work (e.g., daily/weekly/monthly checks about the safety measures such as earth resistance, neutral to earth voltage, lighting illumination, lubrication for bearings, cleaning of Conveyors, input air pressure and its leakage systems, fire alarm etc.)

Lone working

Permit to work (PTW)

Working safely in confined spaces

Emergency procedures and training

Hazard identification and assessment of risk associated with identified hazard

Use of control measures (ERIC SP)

Production of a Risk Assessment & Method Statement for a maintenance procedure.

LO4 **Apply effective inspection and maintenance techniques relative to a particular specialisation such as mechanical or electrical**

Maintenance techniques:

Importance of isolation and making safe before undertaking maintenance

Adherence to PTW process and shift changeover procedures

In-service (live) preventative maintenance e.g. thermographic survey, partial discharge inspection

Standard Operating Procedure (SOP) − application, and documentation recording systems, and the potential implications on safety, quality, and delivery if they are not adhered to

Compliance with manufacturer's recommended inspection and maintenance procedures, using manufacturer's data as case studies

Look, listen and feel philosophy. Visual inspections

Measurements: electrical and mechanical. Mechanical operations test

Functional tests e.g. exercise switching mechanisms

Application of non-destructive examination (NDE) and non-destructive investigation (NDI) techniques for maintenance e.g. acoustic emission, eddy current, liquid penetrant, ultrasonics, thermography

Recording data and maintenance records.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse the impact of relevant statutory regulations and organisational safety requirements on the industrial workplace		
P1 Describe the key features of health and safety regulations in the workplace. **P2** Analyse the role of the Health and Safety Executive in health and safety in the workplace.	**M1** Assess the consequences of employers not abiding by health and safety legislation and regulations, and risk assessment in the workplace.	**D1** Evaluate the likely consequences of non-adherence to relevant health and safety legislation, and risk prevention measures by employers and employees. **D2** Critically appraise the potential impact of a workplace inspection by a Health and Safety Executive inspector including the role of Safety Data Sheet (SDS).
LO2 Differentiate between the merits and use of different types of maintenance strategies in an industrial workplace		
P3 Differentiate methods used to complete engineering maintenance in an industrial workplace. **P4** Discuss the advantages and disadvantages of different strategies to complete maintenance in an industrial workplace.	**M2** Explain the importance of selecting relevant maintenance methods and carrying out engineering maintenance in an industrial workplace.	**D3** Illustrate the most appropriate maintenance system in an industrial workplace. **D4** Assess the likely consequences of not completing a maintenance regime in an industrial workplace.

Pass	Merit	Distinction
LO3 Illustrate competence in working safely by correctly determining the hazards and risks associated with maintenance techniques		
P5 Illustrate various methods used to identify risks and their associated hazards. **P6** Carry out a risk assessment on a typical maintenance technique.	**M3** Discuss the importance of completing risk assessments. **M4** Explain how control measures are used to prevent accidents. **M5** Complete a method statement for a typical maintenance technique.	**D5** Analyse, using actual workplace procedures, the methods used such as SOP to deal with identified hazards in accordance with statutory legal requirements and workplace policies and recommend improvements.
LO4 Apply effective inspection and maintenance techniques relative to a particular specialisation such as mechanical or electrical		
P7 Apply effective inspection and maintenance techniques in an industrial or simulated environment, recording the appropriate sequence of procedures.	**M6** Analyse the effectiveness of these inspection and maintenance techniques in plant asset management.	**D6** Justify appropriate inspection and maintenance techniques across industrial plant assets.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Affleck E. (2022) *Maintenance Engineering.* New York: Larsen and Keller Education.

Baptista J. (2020) *Industrial Maintenance: Techniques, Stories, and Cases.* Boca Raton, Florida: CRC Press.

Dhillon B.S. (2023) *System Safety, Maintainability, and Maintenance for Engineers.* Boca Raton, Florida: CRC Press.

Hellier C.J. (2020) *Handbook of nondestructive evaluation*. 3rd Ed. New York: McGraw-Hill Education.

Mobley R.K. (2014) *Maintenance Engineering Handbook*. 8th Ed. New York: McGraw-Hill Education.

Peng K. (2021) *Equipment Management in the Post-Maintenance Era: Advancing in the Era of Smart Machines.* 2nd Ed. Boca Raton, Florida: Productivity Press.

Richardson D.C. (2013) *Plant Equipment & Maintenance Engineering Handbook*. New York: McGraw-Hill Education.

The Institution of Engineering and Technology (IET) (2022) *Guide to Electrical Maintenance (IET Codes and Guidance*. London: IET.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Journal of Nondestructive Evaluation

Journal of Quality in Maintenance Engineering

Non-Destructive Testing

Nondestructive Testing and Evaluation

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4025: Operations and Plant Management.

Unit 4019: Electrical and Electronic Principles

Unit Code: F/651/0737

Level: 4

Credits: 15

Introduction

Electrical engineering is mainly concerned with the movement of energy and power in electrical form, and its generation and consumption. Electronics is mainly concerned with the manipulation of information, which may be acquired, stored, processed or transmitted in electrical form. Both depend on the same set of physical principles, though their applications differ widely. A study of electrical or electronic engineering depends very much on these underlying principles; these form the foundation for any qualification in the field, and are the basis of this unit.

The physical principles themselves build initially from our understanding of the atom, the concept of electrical charge, electric fields, and the behaviour of the electron in different types of material. This understanding is readily applied to electric circuits of different types, and the basic circuit laws and electrical components emerge. Another set of principles is built around semiconductor devices, which become the basis of modern electronics. An introduction to semiconductor theory leads to a survey of the key electronic components, primarily different types of diodes and transistors.

Electronics is very broadly divided into analogue and digital applications. The final section of the unit introduces the fundamentals of these, using simple applications. Thus, under analogue electronics, the amplifier and its characteristics are introduced. Under digital electronics, voltages are applied as logic values, and simple circuits made from logic gates are considered.

On successful completion of this unit students will have a good and wide-ranging grasp of the underlying principles of electrical and electronic circuits and devices, and will be able to proceed with confidence to further study.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Apply an understanding of fundamental electrical quantities to analyse circuits with constant voltages and currents

LO2 Analyse circuits with sinusoidal voltages and currents

LO3 Describe the basis of semiconductor action, and its application to simple electronic devices

LO4 Explain the difference between digital and analogue electronics, describing simple applications of each.

Essential Content

LO1 **Apply an understanding of fundamental electrical quantities to analyse circuits with constant voltages and currents**

Fundamental electrical quantities and concepts:

Charge, current, electric field, energy in an electrical context, potential, potential difference, resistance, electromotive force, conductors, insulators, and electrical power

Modern applications examples of electrical systems.

Circuit laws:

Voltage sources, Ohm's law, resistors in series and parallel, the potential divider

Kirchhoff's laws, Thevenin's theorem, Norton's theorem, superposition.

Energy and power:

Transfer into the circuit through, for example, battery, solar panel or generator, and out of the circuit as heat or mechanical. Maximum power transfer theorem

Power analysis and test methods.

LO2 **Analyse circuits with sinusoidal voltages and currents**

Fundamental quantities of periodic waveforms:

Frequency, period, peak value, phase angle, waveforms, the importance of sinusoids.

Mathematical techniques:

Trigonometric representation of a sinusoid. Rotating phasors and the phasor diagram. Complex notation applied to represent magnitude and phase.

Reactive components:

Principles of the inductor and capacitor. Basic equations, emphasising understanding of rates of change (of voltage with capacitor, current with inductor). Current and voltage phase relationships with steady sinusoidal quantities, representation on phasor diagram; Inductor and capacitor applications.

Circuits with sinusoidal sources:

Current and voltage in series and parallel RL, RC, LC and RLC circuits.

Transient and Steady State analysis of RL, RC, LC and RLC circuits

Reactance, impedance, resonance, bandwidth, quality factor

Time and frequency response of filters

Mains voltage single-phase systems. Active power, reactive power, complex Power, root-mean-square power quantities, power factor

Introduction to DC and AC generators/motors, introduction to three phase power systems.

Ideal transformer and rectification:

The ideal transformer, half-wave and full-wave rectification. Use of smoothing capacitor, ripple voltage.

LO3 **Describe the basis of semiconductor action, and its application to simple electronic devices**

Semiconductor material:

Characteristics of semiconductors; impact of doping, p-type and n-type semiconductor materials, the p-n junction in forward and reverse bias.

Simple semiconductor devices:

Characteristics and simple operation of junction diode, Zener diode, light emitting diode, bipolar transistor, Junction Field Effect Transistor (FET) and Metal Oxide Semiconductor FET (MOSFET). The bipolar transistor as switch and amplifier.

Simple semiconductor applications:

Diodes: AC-DC rectification, light emitting diode, voltage regulation

Transistors: switches and signal amplifiers

Modern applications examples of electronic devices.

LO4 **Explain the difference between digital and analogue electronics, describing simple applications of each**

Analogue concepts:

Analogue quantities, examples of electrical representation of, for example, audio, temperature, speed, or acceleration

The voltage amplifier; gain, frequency response, input and output resistance, effect of source and load resistance (with source and amplifier output modelled as Thevenin equivalent)

Introduction to operational amplifiers.

Digital concepts:

Logic circuits implemented with switches or relays

Use of voltages to represent logic 0 and 1, binary counting

Logic Gates (AND, OR, NAND, NOR) to create simple combinational logic functions

Truth Tables.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply an understanding of fundamental electrical quantities to analyse circuits with constant voltages and currents		
P1 Apply the principles of circuit theory to simple circuits with constant sources, to explain the operation of that circuit.	**M1** Apply the principles of circuit theory to a range of circuits with constant sources, to explain the operation of that circuit.	**D1** Examine the operation of a range of circuits with constant sources, including power analysis, using relevant circuit theories.
LO2 Analyse circuits with sinusoidal voltages and currents		
P2 Analyse RLC circuits, using the principles of circuit theory with sinusoidal sources.	**M2** Analyse RLC circuits, using the principles of circuit theory and mathematical techniques used with sinusoidal sources.	**D2** Evaluate the operation and behaviour of series and parallel RLC combined circuits, including resonance and using the principles of circuit theory with sinusoidal sources.
LO3 Describe the basis of semiconductor action, and its application to simple electronic devices		
P3 Describe the behaviour of a p-n, pnp, npn junctions in terms of semiconductor behaviour. **P4** Demonstrate the action of a range of semiconductor devices in both analytical and practical settings.	**M3** Analyse the operation of a range of discrete semiconductor devices in terms of simple semiconductor theory.	**D3** Discuss the performance of a range of semiconductor devices in terms of simple semiconductor theory and their applications.
LO4 Explain the difference between digital and analogue electronics, describing simple applications of each		
P5 Explain the difference between digital and analogue electronics. **P6** Explain the operation and characteristics of amplifiers in analytical and practical settings. **P7** Examine the operation of logic circuits in analytical and practical settings.	**M4** Critique the benefits and drawbacks of using analogue and digital electronic devices using examples.	**D4** Evaluate the use of analogue and digital devices and circuits in specific applications.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Boylestad R.L., Nashelsky, L. (2013) *Electronic devices and circuit theory*. Pearson.

Boylestad R.L. (2023) *Introductory Circuit Analysis.* Global Edition. 14th Ed. Pearson.

Bird J. (2013) *Electrical Circuit Theory and Technology*. Routledge.

Hughes E., Hiley, J., Brown, K. and McKenzie-Smith, I. (2016) *Electrical and Electronic Technology*. 12th Ed. Pearson.

Floyd T.L. (2017) *Digital fundamentals.* 11th Ed. Global Edition. Pearson.

Mohindru P. and Mohindru P. (2022) *Electronic Circuit Analysis using LTSpice XVII Simulator: A Practical Guide for Beginners.* 1st Ed. CRC Press.

Singh K. (2011) *Engineering Mathematics through Applications*. 2nd Ed. Palgrave.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advances in Electrical Engineering, Electronics and Energy

Electronic Letters

Electronics World Magazine

Everyday Practical Electronics Magazine

IEEE Transactions on Circuits and Systems

IEEE Transactions on Industrial Electronics and Power Electronics

Industrial Economics Society

Journal of Electrical and Electronic Engineering

New Electronics Digital Magazine

Links

This unit links to the following related units:

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 4020: Digital Principles

Unit Code: J/651/0739

Level: 4

Credits: 15

Introduction

While the broad field of electronics covers many aspects, it is digital electronics which now has the greatest impact. This is immediately evident in the mobile phone, laptop, and numerous other everyday devices and systems. Digital electronics allows us to process, store, and transmit data in digital form in robust ways, which minimises data degradation.

The unit introduces digital principles and the two main branches of digital electronics, combinational and sequential. Thus, the student gains familiarity in the fundamental elements of digital circuits, notably different types of logic gates and bistables. The techniques by which such circuits are analysed, introduced, and applied, including Truth Tables, Boolean Algebra, Karnaugh Maps, and Timing Diagrams.

The theory of digital electronics has little use unless the circuits can be built – at low cost, high circuit density, and in large quantity. Thus, the key digital technologies are introduced. These include the conventional TTL (Transistor-Transistor Logic) and CMOS (Complementary Metal Oxide Semiconductor). Importantly, the unit moves on to programmable logic, including the Field Programmable Gate Array (FPGA). Finally, some standard digital subsystems, which become important elements of major systems such as microprocessors, are introduced and evaluated.

On successful completion of this unit students will have a good grasp of the principles of digital electronic circuits, and will be able to proceed with confidence to further study.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain combinational logic circuits

LO2 Interpret sequential logic circuits

LO3 Describe the technologies used to implement digital electronic circuits

LO4 Analyse a range of digital subsystems, hence establishing the building blocks for larger systems.

Essential Content

LO1 **Explain combinational logic circuits**

Concepts and applications:

Digital principles, logic design and logic circuits, real-world applications, and history and future trends.

Concepts of combinational logic:

Logic circuits implemented with electro-mechanical switches and transistors. Circuits built from AND, OR, NAND, NOR, XOR gates to achieve logic functions, e.g. majority voting, simple logical controls, adders.

Number systems, and binary arithmetic:

Binary, Decimal, Hexadecimal number representation, converting between, applications and relative advantages. Addition and subtraction in binary, range of *n*-bit numbers.

Analysis of logic circuits:

Truth Tables, Boolean Algebra, de Morgan's theorem, Karnaugh Maps

Simplification and optimisation of circuits using these techniques.

LO2 Interpret sequential logic circuits

Sequential logic elements and circuits:

SR latch built from NAND or NOR gates

Clocked and edge-triggered bistables, D and JK types

Simple sequential circuits, including shift registers and counters

Timing Diagrams.

Memory technologies:

Memory terminology, overview of memory technologies including Static RAM, Dynamic RAM and Flash memory cells

Relative advantages in terms of density, volatility and power consumption

Typical applications, e.g., in memory stick, mobile phone, laptop.

LO3 Describe the technologies used to implement digital electronic circuits

Logic values represented by voltages:

The benefit of digital representation of information

The concept of logic input and output values and thresholds.

Digital technologies:

Introduction to discrete logic families, CMOS and TTL, relative advantages in terms of speed, power consumption, density

Programmable logic, FPGAs, relative advantages and applications

Practical applications and the future of digital technologies.

LO4 Analyse a range of digital subsystems, hence establishing the building blocks for larger systems

User interface:

Examples to include switches, light emitting diodes and simple displays

Digital subsystems:

Examples to be drawn from adders (half, full, *n*-bit), multiplexers and demultiplexers, coders and decoders, counters applied as timers, shift registers applied to serial data transmission, elements of the ALU (Arithmetic Logic Unit). Emphasis on how these can be applied, and how they might fit into a larger system.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain combinational logic circuits		
P1 Explain the operation of combinational logic circuits, making use of Truth Table, Boolean Algebra and Karnaugh Map.	**M1** Analyse the operation of a combinational logic circuit making good use of Truth Table, Boolean Algebra and Karnaugh Map.	**D1** Design combinational logic circuits by making best use of Truth Table, Boolean Algebra and Karnaugh Map.
LO2 Interpret sequential logic circuits		
P2 Interpret the operation of a sequential logic circuit, making use of Timing Diagrams.	**M2** Analyse simple sequential logic circuits, making use of Timing Diagrams.	**D2** Design sequential logic circuits, making use of Timing Diagrams.
LO3 Describe the technologies used to implement digital electronic circuits		
P3 Describe the technologies used to implement electronic circuits.	**M3** Apply techniques using lab equipment to configure and test simple digital circuits.	**D3** Apply techniques using lab equipment to configure, test and evaluate digital circuits, comparing and evaluating characteristics of different technologies.
LO4 Analyse a range of digital subsystems, hence establishing the building blocks for larger systems		
P4 Analyse the principles of a range of different logic subsystems.	**M4** Analyse a range of different logic subsystems in context of larger systems.	**D4** Evaluate a range of different logic subsystems, comparing these with other techniques or subsystems available, indicating the place they might take in a larger system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Dally W.J. and Harting, R.C. (2012) *Digital Design: A systems approach.* Cambridge University Press

Fadali M.S. and Visioli A. (2019) *Digital Control Engineering.* 3rd Ed. Academic Press

Floyd T.L. (2017) *Digital Fundamentals*. Global Edition. 11th Ed. Pearson

Hughes E., Hiley J., Brown K. and McKenzie-Smith, I. (2016) *Electrical and Electronic Technology*. 12th Ed. Pearson

Kleitz W. (2013) *Digital Electronics.* 9th Ed. Pearson

Kolawole M. O. (2021) *Electronics: from Classical to Quantum.* 1st Ed. CRC Press.

Mano M. (2016) *Digital Logic and Computer Design Paperback.* 4th Ed. Pearson.

Mazumder P. and Ebong i.e. (2023) *Lectures on Digital Design Principles.* 1st Ed. River Publishers

Plonus M. (2020) *Electronics and Communications for Scientists and Engineers*. 2nd Ed. Butterworth-Heinemann

Twomey J. (2023) *Applied Embedded Electronics.* O'Reilly Media, Inc.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Electronics

Electronic Letters

e-Prime – Advances in Electrical Engineering, Electronics and Energy

IEEE Digital Circuits and Systems

IET Computers and Digital Techniques

International Journal of Digital Electronics

International Journal of Electronics

International Journal of Electronics and Communications

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 4021: Electrical Machines

Unit Code: **M/651/0740**

Level: **4**

Credits: **15**

Introduction

Electrical machines are used to convert electrical energy to and from mechanical energy. These are found in manufacturing, transport, consumer appliances, medical and other sectors. People will come across them every day in their home and at work. Electric machines are bidirectional electromechanical energy conversion devices that can be looked in two ways; as a motor which converts electrical energy to mechanical energy; or as a generator which converts mechanical energy to electrical energy. Transducers and actuators are also energy converters and can be found in a wide range of industrial and domestic applications.

This unit introduces students to the construction, modelling and characteristics of a range of electromagnetic machines and their practical application.. Among the topics included in this unit are: principles underlying the operation and construction of brushed DC, induction, and synchronous machines (motors and generators), electromagnetic transducers and actuators; and operating characteristics of electrical machines such as voltage, current, speed, torque, power rating, electromagnetic interference (EMI) and efficiency.

On successful completion of this unit, students will be able to gain knowledge and understanding of the operating characteristics of different types of electrical machines and their practical applications in the industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate the different types and operation of electrical machines

LO2 Explore the operation and the various starting methods of induction machines

LO3 Explore the operation and the various starting methods of synchronous machines

LO4 Analyse the operating characteristics, construction and applications of electromagnetic transducers and actuators.

Essential Content

LO1 Investigate the different types and operation of electrical machines

Constructional features:

Construction, application and characteristics and operation of machine types such as: DC brushed, single phase induction, three phase induction, universal, types of synchronous (BLDC/BLAC, wound rotor)

Stator, rotor, windings, commutator/slip rings, bearings, case, cooling.

Typical applications of a range of electrical machines (generators/motors), possible modes of operation (torque, speed, position), and how they are chosen for a specific application (based on key performance parameters: torque-speed characteristic, losses, efficiency, size, cost, etc.).

Brushed and brushless DC machines:

Brushed versus brushless; advancements and case studies.

Brushed DC machine equivalent circuit model, analysis of the circuit, testing/characterising.

LO2 Explore the operation and the various starting methods of induction machines.

Methods and applications:

Characteristics and testing (characterisation) of induction machines (locked rotor and no-load tests)

Equivalent circuit model of one phase with magnetising branch approximation.

Starting methods

Direct On-Line (DOL)

Star/Delta

Variable Frequency Drives (VFD)

Operation, key characteristics, and parameters:

Voltages, power, speed, torque, inertia, EMI, efficiency, and safety (including health and safety policies, procedures and regulations, compliance, risk assessment process and procedures)

Protection devices.

LO3 **Explore the operation and the various starting methods of synchronous machines**

Operation and characteristics of synchronous machines:

Characteristics and testing of synchronous machines (too much load can cause them to lose sync and torque)

Focus on two types: Permanent Magnet Synchronous Machines (PMSM – Brushless AC) and the wound rotor for larger applications (grid power generation)

Starting methods (Closed loop control of PMSM with a VFD)

Practical applications

Equivalent circuit model

Voltages, power, speed, torque, inertia, EMI, efficiency

Cooling and protection.

LO4 **Analyse the operating characteristics, construction and applications of electromagnetic transducers and actuators.**

Operating characteristics:

Construction, application, characteristics and testing of electromagnetic transducers and actuators

Transducer types (active, passive, sensor), actuator types (solenoids, linear, rotary including stepper motors)

Practical applications

Voltage and current requirements, hysteresis, and speed of operation.

Torque/force

Insulation Protection (IP) rating

Contact types

Back Electromotive Force (EMF), EMI and efficiency.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the different types and operation of electrical machines.		
P1 Examine the types of electrical machine used in industry. **P2** Discuss suitable applications for electrical machines in industry. **P3** Investigate key parameters of a brushed DC machine.	**M1** Illustrate the operation of the brushed DC machine, considering the equivalent circuit.	**D1** Assess the appropriateness of different types of electrical machine for an actual operational requirement.
LO2 Explore the operation and the various starting methods of induction machines		
P4 Explore the operating principles of the three-phase induction machine. **P5** Analyse the different methods of starting three- and single-phase induction machines.	**M2** Demonstrate the characterisation of the three-phase induction machine, considering the equivalent circuit.	**D2** Critically evaluate the efficiency of available induction machines and make a recommendation for a specific operational requirement.
LO3 Explore the operation and the various starting methods of synchronous machines		
P6 Explain the operating principles of a permanent magnet synchronous machine. **P7** Explore a synchronous machine for a specific application, considering their operating characteristics.	**M3** Justify the use of a wound-rotor synchronous machine in a specific application.	**D3** Assess the performance and efficiency of permanent-magnet synchronous machines and make a recommendation for a specific operational requirement.
LO4 Analyse the operating characteristics, construction and applications of electromagnetic transducers and actuators		
P8 Analyse the operation, types and uses of electromotive transducers and actuators, by examining features that support their suitability for specific applications.	**M4** Justify the selection of suitable transducers for specific industrial applications.	**D4** Critically analyse the practical application of transducers and actuators in an industrial situation and make recommendations to improve their operating effectiveness.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Boldea I. and Tutelea L.N. (2021) *Electrical Machines: Steady State and Performance with MATLAB*. 2nd Ed. CRC Press

Boldea I. and Tutelea L.N. (2021) *Electrical Machines: Two Volume Set.* 2nd Ed. CRC Press

Chapman S.J. (2011) *Electric Machinery Fundamentals*. 5th Ed. McGraw-Hill

De Silva, C.W. (2015) *Sensors and Actuators: Engineering System Instrumentation*. 2nd Ed. CRC Press

Fucha E.F. and Masoum M.A.S. (2023) *Power Quality in Power Systems, Electrical Machines, and Power-Electronic Drives*. 3rd Ed. Academic Press

Gibbons P.(Editor) (2023) *Electrical Machines: Analysis and Applications* (Hardback). Clanrye International.

Gieras J.F. (2020) *Electrical Machines: Fundamentals of Electromechanical Energy Conversion*. CRC Press

Guru B.S. and Hiziroglu H.R. (2001) *Electric Machinery and Transformers*. 3rd Ed. Oxford university Press

Hughes, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications*. 4th Ed. Newnes

Krishnan R. (2001) *Electric Motor Drives: Modeling, Analysis, and Control* Paperback – Illustrated. Pearson.

Alassouli H.M. (2021) *Lecture Notes for Electrical Machines Course*. Self-published.

Sarma M.S. (1997) *Electrical Machines: Steady-State Theory and Dynamic Performance*. 2nd Ed. CL Engineering

Sehgal R., Gupta N., Tomar A., Sharma M.D. and Kumaran V. (2022) *Smart Electrical and Mechanical Systems.* 1st Ed. Academic Press

Wildi T. (2014) *Electrical Machines, Drives and Power Systems*. 6th Ed. Pearson New International Edition.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

CES Transactions on Electrical Machines and Systems

Electrical Machines and Control 1007-449X

Electrical machines and Electromechanics

Electrical Machines & Power Systems

International Journal of Electrical Machines & Drives

International Journal of Electrical Power & Energy Systems

Journal of Electrical Engineering & Technology

Links

This unit links to the following related units:

Unit 5010: Further Electrical Machines and Drives.

Unit 4022: Electronic Circuits and Devices

Unit Code: T/651/0742

Level: 4

Credits: 15

Introduction

Electronics is pervasive and impacts various aspects of modern day living and the society as a whole. Many industries rely upon the use of electronics, thereby creating opportunities in industrial applications and research.

This unit introduces students the operational characteristics of amplifier circuits, the types, and effects of feedback on a circuit performance, and the operation, application of oscillators. They will also be introduced to semiconductor devices and circuits, the use of electronics manufacturers' data to analyse the performance of circuits and devices, the application of testing procedures, and use the findings of the tests to evaluate their operation.

Among the topics included in this unit are: power amplifiers, class A, B and AB; operational amplifiers, inverting, non-inverting, differential, summing, integrator, differentiator; types such as open, closed, positive and negative feedback; frequency, stability, frequency drift, distortion, amplitude, wave shapes and testing procedures.

On successful completion of this unit students will be able to learn about the operational characteristics of amplifier circuits, the types and effects of feedback on an amplifier's performance, the operation and application of oscillators and application of testing procedures to electronic devices and circuits.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine the operational characteristics of amplifier circuits

LO2 Investigate the types and effects of feedback on an amplifier's performance

LO3 Examine the operation and application of oscillators

LO4 Apply testing procedures to electronic devices and circuits.

Essential Content

LO1 **Determine the operational characteristics of amplifier circuits**

Operational characteristics:

Power amplifiers: class A, B and AB

Operational amplifiers: inverting, non-inverting, differential, summing, integrator, differentiator, comparator, instrumentation, Schmitt trigger, active filters

Gain, bandwidth, frequency response, input, and output impedance

Distortion and noise.

Electronic circuits and semiconductors:

Integrated use of semiconductors and electronic circuits; diodes and transistors, diode applications, Zener diode; operational characteristics.

LO2 **Investigate the types and effects of feedback on an amplifier's performance**

Types and effects:

Types including open, closed, positive and negative feedback

Effect of feedback on gain, bandwidth, distortion, noise, stability, input, and output impedance

The concept of virtual ground.

LO3 **Examine the operation and application of oscillators**

Operation and application:

Types of oscillators such as Wien bridge, Twin-T, R-C ladder, L-C coupled, transistor, operational amplifier, crystal

Frequency, stability, frequency drift, distortion, amplitude, and wave shapes.

LO4 **Apply testing procedures to electronic devices and circuits**

Testing procedures:

Measuring performance, using practical results and computer simulations

Voltage gain, current, bandwidth, frequency response, output power, input, and output impedance

Distortion and noise.

Devices to test:

Introduction of concepts, device usage and testing

Semiconductors

Integrated circuits

Amplifiers

Oscillators

Filters

Power supplies

Integrated circuit (IC) voltage regulators

Combined analogue and digital IC's.

Component manufacturer's data:

Specifications, manuals, and circuit diagrams.

Use of testing equipment:

Meters, probes, and oscilloscopes

Signal generators and signal analysers, logic analysers

Virtual test equipment (simulation software)

Effective use of tools and techniques when securely operating and testing systems and components (e.g., networks and devices).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine the operational characteristics of amplifier circuits		**D1** Critically review the results obtained from the application of practical and simulated tests on amplifier circuits studied.
P1 Describe the types of amplifiers available using their typical circuits. **P2** Determine different performance characteristics of types of operational amplifier.	**M1** Explain the results obtained from applying practical tests on an amplifier's performance.	
LO2 Investigate the types and effects of feedback on an amplifier's performance		**D2** Analyse the effect of feedback on an amplifier's performance using practical and simulated tests.
P3 Investigate the effect of different types of feedback on the operational amplifier's performance. **P4** For a given practical scenario, describe how circuits employ feedback.	**M2** Perform practical tests to show the effect of feedback on an amplifier's performance.	
LO3 Examine the operation and application of oscillators		**D3** Analyse the results obtained from applying practical and simulated tests to oscillators studied.
P5 Examine types of available oscillators and their applications.	M3 Assess the performance characteristics of different type of oscillators.	
LO4 Apply testing procedures to electronic devices and circuits		**D4** Critically review the results obtained from applying practical and simulated tests to devices and circuits studied.
P6 Show use of manufacturer's data sheets in selecting electronic devices for a given context. **P7** Apply information derived from manufacturer's data when testing electronic devices and circuits.	**M4** Perform tests on electronic devices and circuits, recording results and recommending appropriate action.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird Jo. (2022) *Bird's Electrical Circuit Theory and Technology*. 7th Ed. Routledge

Boylestad R.L. and Nashelsky L. (2013) *Electronic Devices and Circuit Theory*. 11th Ed. Pearson

Floyd T.L. and Buchla D. (2021) *Electronics Fundamentals: Conventional Current*. 10th Ed. Pearson

Horowitz P. and Hill W. (2015) *The Art of Electronics*. 3rd Ed. Cambridge University Press

Makarov S., Ludwig R. and Bitar S.J. (2019) *Practical Electric Engineering.* 2nd Ed. Springer.

Storey N. (2017) *ELECTRONICS A Systems Approach.* 6th Ed. Pearson

Yawale S. and Yawale S. (2022) *Operational Amplifier: Theory and Experiment.* 1st Ed. Springer.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Electronic Devices and Networking Journal

Electronic Devices Articles from Across Nature Portfolio

IEEE Transactions on Electron Devices

Microelectronics Journal

Power Electronic Devices and Components

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit 5014: Analogue Electronic Systems.

Unit 4023: Computer Aided Design and Manufacture (CAD/CAM)

Unit Code: A/651/0744

Level: 4

Credits: 15

Introduction

The capacity to quickly produce finished components from a software model is now essential in the competitive world of manufacturing. Businesses now invest heavily in Computer Aided Design (CAD) software, Computer Aided Manufacture (CAM) software and Computer Numerical Control (CNC) machines (Additive Manufacture (AM)) and subtractive machining) to facilitate this, thus reducing product lead times. CAD gives design engineers the platform to creatively model components that meet the specific needs of the consumer. When these models are combined with CAM software, manufacturing is made a reality.

This unit introduces students to all the stages of the CAD/CAM process and to the process of modelling components using CAD software specifically suitable for transferring to CAM software. Among the topics included in this unit are: programming methods, component set-up, tooling, solid modelling, geometry manipulation, component drawing, importing solid model, manufacturing simulation, data transfer, CNC machine types, and inspections.

On successful completion of this unit students will be able to learn about the key principles of manufacturing using a CAD/CAM system; 3D solid models of a component suitable for transfer into a CAM system; CAM software to generate manufacturing simulations of a component; and designing a dimensionally accurate component on a CNC machine or AKM system using a CAD/CAM system.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the key principles of manufacturing using a CAD/CAM system

LO2 Prepare 3D solid models of a component suitable for transfer into a CAM system

LO3 Use CAM software to generate manufacturing simulations of a component

LO4 Produce a dimensionally accurate component on a CNC/AM machine using a CAD/CAM system.

Essential Content

LO1 Describe the key principles of manufacturing using a CAD/CAM system

Hardware:

CAD workstation, printers, USB flash drives and network cables.

Software:

Operating systems, hard disk requirements, processor, CAD software e.g., SolidWorks, Autodesk Inventor, CATIA, Creo, Siemens NX; CAM software e.g., FeatureCam, Edgecam, GibbsCAM, SolidCAM, Cura.

Inputs:

CAD model, material specifications, tooling data, spindle speeds and feed rate data calculations, STL file, sliced 3D models (infill, wall thicknesses, material, speeds).

Outputs:

CAM files (eg .stp file), program code (gcode) and coordinates, manufacturing sequences, tooling requirements, auxiliary data.

Programming methods:

CAD/CAM, manual programming, conversational programming.

Component set-up:

Zero datum setting, tool set-up and offsets, axis of movements.

Work-holding:

Machine vice, chuck, fixtures, clamping, jigs.

Tooling:

Milling cutters, lathe tools, drills, specialist tooling, tool holders, tool turrets and carousels.

Overview of emerging technologies:

Industry case studies (e.g., Additive Manufacturing/3D printing).

LO2 **Prepare 3D solid models of a component suitable for transfer into a CAM system**

Solid modelling:

Sketch commands, extrude, cut, holes, sweep, revolve, shell, fillet, chamfer. Use lines, arcs, points, construction planes to generate surface forms. Assign material to review properties of solid models e.g., mass, centre of gravity, surface area.

Geometry manipulation:

Mirror, drag, rotate, copy, array, offset. Model tree manipulation and reordering.

Component/Assembly drawing:

Set-up template, orthographic and multi-view drawings, including sections, detail and exploded views, scale, dimensions, drawing from 3D model data.

Implementation of BS8888 (UK's national framework standard for engineering drawings and geometrical tolerancing)

Attributes e.g., Notes, Bill of Materials (BOM), material, reference points, tolerances, finish, nomenclature (naming convention, e.g. part numbering).

LO3 **Use CAM software to generate manufacturing simulations of a component**

Import solid model:

Set-up, model feature and geometry identification, stock size, material.

Manufacturing simulation:

Operations e.g., roughing and finishing, pockets, slots, profiling, holes, tool and work change positions, tool sizes and IDs, speeds and feeds, cutter path simulations, program editing

CADCAM used in production of Additive Manufacturing (3D Printing)

Use of Industry 4.0 and CAD/CAM: connectivity, advanced toolpaths, testing; integration of systems through simulation.

LO4 **Produce a dimensionally accurate component on a CNC/AM machine using a CAD/CAM system**

CNC machine types:

Machining centres, turning centres, hybrid machining (e.g. Mazak, HAAS, Meltio), Robotic arm/gantry routers, MCUs e.g., Fanuc, Siemens, and Heidenheim.

AM machine types:

FDM, SLS, SLM, SLA (VP), DED, L-PBF, EB-PBF.

Data transfer:

Structured data between CAD and CAM software e.g., datum position and model orientation; file types e.g., SLDPRT, parasolid, STL, IGES, STEP, DXF, gcode; transfer to CNC machine e.g., network, USB, Ethernet, Dashboard UI.

Inspection:

Manual inspection e.g., using Micrometer, Vernier gauges, bore micrometres, thread gauge, radius guage, go-no-go gauge.

Automated inspection e.g., co-ordinate measuring machine (CMM), stages of inspection throughout manufacturing process, Machine Vision inspection, metrology level 3D scanner.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the key principles of manufacturing using a CAD/CAM system		
P1 Describe the hardware and software elements of a typical CAD/CAM system. **P2** Describe, with examples, the inputs and outputs of the CAD/CAM process. **P3** Explain the different methods of component set-up, work-holding/build plate adhesion and tooling/nozzle type/configuration available on CNC/AM machines.	**M1** Analyse the suitability of different programming methods of CNC/AM machines.	**D1** Critically evaluate, using illustrative examples, the impact of different machining conditions and specifications on component manufacturing.
LO2 Prepare 3D solid models of a component suitable for transfer into a CAM system		
P4 Prepare a CAD solid model of a component or multi-part assembly to be manufactured on a computer numerically controlled systems. **P5** Design a working drawing of a component/assembly containing specific manufacturing detail.	**M2** Assess the importance of using different geometry manipulation methods for efficient model production. **M3** Analyse accuracy aspects of drawing to aid inspection.	**D2** Critically evaluate the effectiveness of using a CAD/CAM system and solid modelling to manufacture components.

Pass	Merit	Distinction
LO3 Use CAM software to generate manufacturing simulations of a component		**D3** Analyse the effect of applying different manufacturing techniques and modifications to achieve an optimised production time.
P6 Use CAM software to generate a geometrically accurate CAD solid model of a component.	**M4** Using CAM software, generate cutter tool path simulations. **M5** Review sliced file/toolpath, part orientation, infill, supports, wall thickness, build plate adhesion.	
LO4 Produce a dimensionally accurate component on a CNC/AM machine using a CAD/CAM system		**D4** Critically analyse, giving illustrative examples, the different methods of data transfer through a CAD/CAM system.
P7 Produce a part program for a component using CAM software and transfer the part program to a CNC/AM machine and manufacture a component. **P8** Describe the structural elements of a CNC Machining Centre or 3D Printer. **P9** Review a component manufactured on a CNC/AM machine to verify its accuracy.	**M6** Compare different methods of component inspection used in manufacturing.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bethune J.D. (2019) *Engineering Design Graphics with Autodesk Inventor 2020*. 1st Ed. Pearson.

Bi Z. and Wang X. (2020) *Computer Aided Design and Manufacturing*. Wiley.

BS 8888 (2017) *Technical product documentation and specification*.

Chang K.H. (2021) *Virtual Machining Using CAMWorks 2021 − CAMWorks as a SOLIDWORKS Module*. 1st Ed. SDC Publications.

Chitale A.K. and Gupta R.C. (2023) *Product design and manufacturing*. PHI Learning Pvt. Ltd.

Confalone G.C., Smits J. and Kinnare T. (2023) *3D Scanning for Advanced Manufacturing, Design, and Construction*. Wiley.

Groover M.P. (2020) *Fundamentals of modern manufacturing: materials, processes, and systems*. John Wiley & Sons.

Metwalli S.M. (2021) *Machine Design with CAD and Optimization*. Wiley.

Omura G. and Benton B.C. (2014) *Mastering AutoCAD 2015 and AutoCAD LT 2015 Essentials*. Autodesk Official Press

Pitroda H. P (2019) *Computer Aided Design: Textbook and Practice book*. Walnut publication

Sarkar J., (2014). *Computer aided design: a conceptual approach*. CRC Press.

Shih R.H. (2024) *Principles and Practice: An Integrated Approach to Engineering Graphics and AutoCAD 2024*. 1st Ed. SDC Publications.

Simmons C.H., Dennis E. and Maguire N.P. (2020) *Manual of Engineering Drawing-British and International Standards.* 5th Ed. Butterworth-Heinemann.

Stark J. (2021) *What Every Engineer Should Know about Practical CAD/CAM Applications.* CRC Press.

Zeus Precision Charts Ltd. (2007) *Zeus Precision Data Charts and Reference Tables for Drawing Office, Toolroom & Workshop*. Metric Revision.

Journals:

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

CAD Journal – CAD and Applications

Computer-Aided Design

Computer-Aided Design and Applications

International journal of Computer Integrated manufacturing

International Journal of CAD/CAM

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4027: CAD for maintenance Engineers

Unit 4034: Computer Aided Design (CAD) for Engineering

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit Code: F/651/0746

Level: 4

Credits: 15

Introduction

Hydraulics and pneumatics incorporate the importance of fluid power theory in modern industry. This is the technology that deals with the generation, control, and movement of mechanical elements or systems with the use of pressurised fluids in a confined system. In respect of hydraulics and pneumatics, both liquids and gases are considered fluids. Oil hydraulics employs pressurised liquid petroleum oils and synthetic oils, whilst pneumatic systems employ an everyday recognisable process of releasing compressed air to the atmosphere after performing the work.

The aim of this module is to develop students' knowledge and appreciation of the applications of fluid power systems in modern industry. Students will investigate and design pneumatic, hydraulic, electro-pneumatic and electro-hydraulic systems. This unit offers the opportunity for students to examine the characteristics of fluid power components and evaluate work-related practices and applications of these systems.

On successful completion of this unit students will be able to learn about applications of hydraulic and pneumatic systems in the production industry, fundamental principles and practical techniques for obtaining solutions to problems, real-life applications of pneumatic and hydraulic systems, and the importance of structured maintenance techniques.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Calculate the parameters of pneumatic and hydraulic systems

LO2 Illustrate the notation and symbols of pneumatic and hydraulic components

LO3 Examine the applications of pneumatic and hydraulic systems

LO4 Investigate the maintenance of pneumatic and hydraulic systems.

Essential Content

LO1 **Calculate the parameters of pneumatic and hydraulic systems**

Pneumatic and hydraulic theory:

Combined and ideal gas laws: Boyle's Law, Charles' Law and Gay-Lussac's Law

Fluid flow, calculation of pressure and velocity using Bernoulli's Equation for Newtonian fluids

System performance, volumetric operational and isothermal efficiency

Dynamic and Kinematic Viscosity

Methods of measuring viscosity including Stokes' Law

Navier Stokes Equations.

LO2 **Illustrate the notation and symbols of pneumatic and hydraulic components**

Performance of hydraulic and pneumatic components:

The use and importance of International Standards, including relative symbols and devices

Fluid power diagrams

Pneumatic and hydraulic critical equipment and their purpose

Circuit diagrams, component interaction and purpose

Dynamics of modern system use.

LO3 **Examine the applications of pneumatic and hydraulic systems**

System applications:

Calculation of appropriate capacities and specifications

Applied functions of control elements

Design and testing of hydraulic and pneumatic systems

Fluid power in real-life examples

Valued component choice

Alternative actuating systems.

LO4 **Investigate the maintenance of pneumatic and hydraulic systems**

Efficiency of systems:

Efficient maintenance: accurate records and procedures to ensure efficiency

Functional inspection, modern techniques to limit production problems, quality control

Testing, efficient procedures to enable component longevity, recommendations

Fault finding, diagnostic techniques, effects of malfunctions, rectification of faults

Use relevant problem-solving tools where applicable e.g root cause analysis (RCA), process failure modes effects analysis (PFMEA), fishbone, practical problem solving (PPS) and advanced product quality planning (APQP)

Job market and opportunities for efficiency and maintenance of pneumatic and hydraulic systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Calculate the parameters of pneumatic and hydraulic systems		
P1 Calculate the change in volume and pressure in pneumatic systems. **P2** Determine the change in volume and pressure in hydraulic systems.	**M1** Using Bernoulli's Equation, calculate values at stationary incompressible flow.	**D1** Develop a presentation analysing fluid viscosity using Stokes' law and validate how this relates to Navier–Stokes equations.
LO2 Illustrate the notation and symbols of pneumatic and hydraulic components		
P3 Show the purpose of components on a given diagram. **P4** Explain the use of logic functions used within circuits. **P5** Illustrate the use of advanced functions and their effect on circuit performance.	**M2** Assess the different factors that impact on actuator choice for a given application.	**D2** Stating any assumptions, compare the applications of practical hydraulic and pneumatic systems.

Pass	Merit	Distinction
LO3 Examine the applications of pneumatic and hydraulic systems		
P6 Examine the design and function of a hydraulic or pneumatic system employed in a modern production environment. **P7** Define the purpose and function of electrical control elements in a given hydraulic or pneumatic system.	**M3** Justify the measures taken to improve circuit design in respect of performance.	**D3** Propose the design modifications that can be introduced to improve the functionality and maintenance of pneumatic and hydraulic systems without creating reliability issues.
LO4 Investigate the maintenance of pneumatic and hydraulic systems		
P8 Recognise system faults and potential hazards in pneumatic and hydraulic systems. **P9** Investigate procedures to ensure efficient maintenance and operation of pneumatic and hydraulic systems.	**M4** Compare construction and operation of hydraulic and pneumatic systems with regards to legislation and safety issues.	**D4** Evaluate the importance of maintenance, inspection, testing and fault-finding in respect of improved system performance.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Esposito A. (2013) *Fluid Power with Applications*, 7th Ed. Pearson

Parr E. A. (2011) *Hydraulics and Pneumatics – A Technician's and Engineer's Guide*. 3rd Ed. Oxford: Butterworth-Heinemann.

Mills D. (2015) *Pneumatic Conveying Design Guide*. 3rd Ed. Elsevier.

Turner I.C. (2021) *Engineering applications of pneumatics and hydraulic*s. Routledge.

Salam M.A. (2022) *Fundamentals of Pneumatics and Hydraulics*. Springer.

Vacca A. and Franzoni G. (2021) *Hydraulic fluid power: fundamentals, applications, and circuit design*. John Wiley & Sons.

Stryczek J. and Warzyńska U. (Editors) (2020) *Advances in Hydraulic and Pneumatic Drives and Control 2020*. Springer Nature.

Parambath J. (2020) *Electro-Pneumatics and Automation*.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Experiments in Fluids

International Journal of Fluid Power

Journal of Hydraulic Engineering

Journal of Hydraulic Research

Links

This unit links to the following related units:

Unit 4011: Fluid Mechanics

Unit 5023: Thermofluids.

Unit 4025: Operations and Plant Management

Unit Code: H/651/0747

Level: 4

Credits: 15

Introduction

The challenges of modern manufacturing industries require today's operations engineers to adopt a multi-skilled methodology when dealing with the array of complex engineering problems they are faced with. Long gone are the days of 'pure' mechanical or electrical maintenance staff; operations engineers may well specialise within one discipline, but they must have the knowledge and ability to safely tackle problems that could encompass many varied engineering fields if they are to keep the wheels of industry in motion.

The underlying aims of this unit are to develop the students' knowledge of the engineering fundamentals that augment the design and operation of plant engineering systems, and to furnish them with the tools and techniques to maintain the ever more technological equipment.

The students are introduced to the concept of thermodynamic systems and their properties in the first learning outcome; this will provide a platform for the topic of heat transfer in industrial applications (as covered in learning outcome four) and underpin their future studies in subsequent units. The second learning outcome examines common mechanical power transmission system elements found in numerous production/manufacturing environments, whilst the third learning outcome investigates fundamental static and dynamic fluid systems.

On completion of this unit students will be able to learn about the fundaments that underpin the operation of the systems they deal with on a daily basis and apply these fundamentals to the successful maintenance of the systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Analyse fundamental thermodynamic systems and their properties

LO2 Investigate power transmission systems

LO3 Determine the parameters of static and dynamic fluid systems

LO4 Examine the principles of heat transfer in industrial applications.

Essential Content

LO1 Analyse fundamental thermodynamic systems and their properties

Fundamental system:

Forms of energy and basic definitions

Definitions of systems (open and closed, isolated) and surroundings

First and second laws of thermodynamics

The gas laws: Charles' Law, Boyle's Law, general gas law and the Characteristic Gas Equation

The importance and applications of pressure/volume diagrams and the concept of work done

Polytropic processes: constant pressure, constant volume, adiabatic and isothermal processes

Use problem solving tools for analysis where relevant – for example, as Root Cause Analysis (RCA) Process Failure Modes Effects Analysis (PFMEA), Fishbone, Practical Problem Solving (PPS) and Advanced Product Quality Planning (APQP)

Relate knowledge and skills on thermodynamics systems to operations and plant management through real-world industry scenarios.

LO2 Investigate power transmission systems

Power transmission:

Flat and v-section belts drives: maximum power and initial tension requirements

Types of power transmissions: mechanical, hydraulic, pneumatic, electrical

Constant wear and constant pressure theories

Gear trains: simple and compound gear trains; determination of velocity ratio; torque and power

Friction clutches: flat, single, and multi-plate clutches; maximum power transmitted

Conical clutches: maximum power transmitted

Relate knowledge and skills on power transmission systems to operations and plant management through real-world industry scenarios.

LO3 Determine the parameters of static and dynamic fluid systems

Fluid flow theory:

Continuity equations

Application of Bernoulli's Equation

Reynolds number; turbulent and laminar flow

Measuring devices for fluids: flow, viscosity, and pressure

Determination of head loss in pipes by D'Arcy's formula, use of Moody diagrams

Immersed surfaces: centre of pressure, use of parallel axis theorem for immersed surfaces

Hydrostatic pressure and thrust on immersed surfaces

Relate knowledge and skills on fluid systems to operations and plant management through real-world industry scenarios.

LO4 Examine the principles of heat transfer in industrial applications

Heat transfer:

Modes of transmission of heat: conduction, convection, and radiation

Heat transfer through composite walls; use of U and k values; example case studies

Recuperator, regenerator, and evaporative heat exchangers

Application of formulae to heat exchangers

Heat losses in thick and thin-walled pipes: optimum lagging thickness.

Case studies:

Example industry applications (e.g., applications relevant to management of abnormal conditions, emergency management and recovery).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse fundamental thermodynamic systems and their properties		
P1 Examine the operation of thermodynamic systems and their properties. **P2** Explain the application of the first law of thermodynamics to appropriate systems. **P3** Analyse the relationships between system constants for a perfect gas.	**M1** Discuss the index of compression in polytrophic processes.	**D1** Illustrate the importance of expressions for work done in thermodynamic processes by applying first principles.
LO2 Investigate power transmission systems		
P4 Calculate the maximum power which can be transmitted by means of a belt. **P5** Calculate the maximum power which can be transmitted by means of a friction clutch. **P6** Investigate the power and torque transmitted through gear trains.	**M2** Analyse the factors that inform the design of an industrial belt drive system.	**D2** Critique the 'constant wear' and 'constant pressure' theories as applied to friction clutches.

Pass	Merit	Distinction
LO3 Determine the parameters of static and dynamic fluid systems		**D3** Compare the practical application of three different types of differential pressure measuring device.
P7 Determine the head losses in pipeline flow. **P8** Calculate the hydrostatic pressure and thrust on an immersed surface. **P9** Determine the centre of pressure on an immersed surface.	**M3** Explore turbulent and laminar flow in Newtonian fluids.	
LO4 Examine the principles of heat transfer in industrial applications		**D4** Differentiate between parallel and counter flow recuperator heat exchangers.
P10 Examine the heat transfer through composite walls. **P11** Apply heat transfer formulae to heat exchangers.	**M4** Explore heat losses through lagged and unlagged pipes.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Badescu V., Lazaroiu G.C. and Barelli L. (Editors) (2019) *Power Engineering − Advances and Challenges Part B: Electrical Power.* 1st Ed. CRC Press.

Berkshire F.H. (2021) *Introductory Incompressible Fluid Mechanics* Paperback. Kindle Edition. Cambridge University Press.

Cachon G. and Terwiesch C. (2023) *Operations Management.* 3rd Edition. McGraw-Hill

Chowdhury T., Chakrabarti A. and Chanda C.K. (2021) *Power Transmission System Analysis Against Faults and Attacks.* 1st Ed. CRC Press.

Dunn D. (2001) *Fundamental Engineering Thermodynamics*. Longman.

Eastop, T.D. and McConkey, A. (1996) *Applied Thermodynamics for Engineering Technologists*. 5th Ed. Prentice Hall.

Hanlon R.T. (2020) *Block by Block: The Historical and Theoretical Foundations of Thermodynamics Paperback.* Kindle Edition. OUP Oxford.

Ghojel J. (2023) *Heat Transfer Basics: A Concise Approach to Problem Solving* (Hardback). Wiley.

lloyd E. (Editor) (2023) *Handbook of Heat Transfer and Fluid Flow* (Hardback). Willford Press.

Massey B.S. and Ward-Smith J. (2011) *Mechanics of Fluids*. 9th Ed. Oxford: Spon Press.

Moran M. J., and Tsatsaronis G. (2017) 'Engineering Thermodynamics'. In *CRC Handbook Of Thermal Engineering* (pp. 1-112). Abingdon: CRC Press.

Pokrovskii V.N. (2020) *Thermodynamics of Complex Systems: Principles and applications − IOP ebooks* (Hardback). Institute of Physics Publishing.

Sarkar D. (2015). *Thermal power plant: design and operation*. Elsevier.

Stevenson W.J (2021) *Operations Management*. 14th Edition. McGraw-Hill.

Vera J.H. and Wilczek-Vera G. (2021) *Classical Thermodynamics of Fluid Systems: Principles and Applications (Paperback).* CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

IEEE Transactions on Power Systems

International Journal of Heat and Mass Transfer

International Journal of Operations and Production Management

International Journal of Services and Operations Management

Journal of Operations Management

Links

This unit links to the following related units:

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit 4026: Electrical Systems and Fault Finding.

Unit 4026: Electrical Systems and Fault Finding

Unit Code: **K/651/0749**

Level: **4**

Credits: **15**

Introduction

Electrical systems can be found in a very wide range of locations such as in manufacturing facilities, airports, transport systems, shopping centres, hotels and hospitals; people will come across them every day in their workplace and at home. The system must take the electrical supply from the national grid, convert it to a suitable voltage and then distribute it safely to the various system components and uses such as electric motors, lighting circuits and environmental controls.

This unit introduces students to the characteristics and operational parameters of a range of electrical system components that are used in a variety of applications; and how to fault find when they go wrong.

On successful completion of this unit students will be able to follow electrical system circuit diagrams, understand the operation of the various components that make up the system and select the most suitable fault-finding technique. Therefore, students will develop skills such as critical thinking, analysis, reasoning, interpretation, decision-making, information literacy, information and communication technology literacy, innovation, creativity, collaboration, and adaptability, which are crucial skills for gaining employment and developing academic competence for higher education progression.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate the key constructional features and applications of electrical systems, including identification and resolution of potential faults

LO2 Examine the types, applications, and common fault-finding methodologies of electrical motors and generators

LO3 Analyse potential faults and fault diagnostics in the various types of lighting circuits available in the industry by assessing their practical application

LO4 Discuss the operating characteristics of electrical safety components including evaluation of their effectiveness through fault-finding techniques.

Essential Content

LO1 **Investigate the key constructional features and applications of electrical systems, including identification and resolution of potential faults**

Electrical systems:

Purpose and types of electrical systems, role of electrical power distribution systems, modern trends and diverse range of applications

Key elements of electrical distribution systems, such as transformers, circuit breakers, protection devices, and wiring techniques. Constructional features of the key elements, for example, transformers such as step up/down, isolating, shell and core, windings, connections, efficiency

Common faults within these systems and the steps to troubleshoot and fix them. Example scenarios include short-circuits, ground faults, and overloads. Non-common and complex faults. Application of tools such as multimeters, circuit testers, and thermal imagers in fault finding could also be covered.

Fault finding, location and signal tracing techniques/methodologies:

Input-to-output, output-to-input, half-split method, symptom to cause fault, unit substitution, visual examination, top-down approach, module and component isolation.

Use of fault-finding aids:

Risk assessment, test plans, functional charts, diagrams, trouble-shooting charts, component data sheets, operation and maintenance manuals, software-based records and data; fault/repair reporting, mean time between failure (MTBF) figures.

LO2 **Examine the types, applications, and common fault-finding methodologies of electrical motors and generators**

Types, methodologies, and applications of electrical motors and generators:

Different types of motors and generators such as DC motors, AC motors, synchronous generators, and induction generators

Current and future uses and industrial applications

Fault finding – typical issues such as winding failures, mechanical failures, control circuit faults; overcurrent, overvoltage and overload

Fault finding/mitigation methodologies for diagnosis, repair, and future maintenance.

LO3 **Analyse potential faults and fault diagnostics in various types of lighting circuits available in the industry by assessing their practical application**

Lighting circuits, applications and fault finding:

Types of lighting circuits such as series and parallel

Combination circuits analysis and use in residential and industry contexts

Lighting design considerations − quality of light, control of glare, luminance, internal/external lighting for visual tasks, emergency lighting

Construction and practical applications

Typical faults including circuit overload, faulty switches, wiring issues; fault diagnostics

Safety requirements for use in hazardous zones.

LO4 **Discuss the operating characteristics of electrical safety components including evaluation of their effectiveness through fault-finding techniques**

Electrical safety components and applications:

Various electrical safety components such as circuit breakers, ground fault interrupters, surge protectors, and safety switches

Operating principles, uses and common malfunctions of electrical safety components

Selection of appropriate component types for a selection of industry scenarios

Role of safety components in protecting equipment and personnel

Techniques to test effectiveness and reliability of safety components (e.g., using an insulation resistance tester)

Electrical safety standards:

Approved codes of practice

Safety first culture and active engagement with health and safety policies and procedures, regulations and compliance, risk assessment process and procedures.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the key constructional features and applications of electrical systems, including identification and resolution of potential faults		
P1 Investigate constructional features of an electrical distribution system, demonstrating the ability to detect and resolve common faults, for a given scenario.	**M1** Analyse constructional features of multiple electrical systems, their applications, with demonstrable proficiency in identifying, diagnosing, and resolving common and less common faults.	**D1** Present modern trends in electrical systems, their constructional features and applications across various industries, with demonstrable knowledge of effective strategies for fault prevention and system optimisation.
LO2 Examine the types, applications, and common fault-finding methodologies of electrical motors and generators.		
P2 Examine the types and applications of electrical motors and generators, and relevant fault-finding methodologies.	**M2** Analyse efficiency aspects of electrical motors and generators in a given application scenario with focus on fault-finding and fault mitigation.	**D2** Perform an examination of a wide range of modern electrical motors and generators and their usage in large applications across diverse industries, with a focus on fault-finding methodologies to diagnose and resolve complex faults.

Pass	Merit	Distinction
LO3 Analyse potential faults and fault diagnostics in the various types of lighting circuits available in the industry by assessing their practical application		
P3 Analyse two types of lighting circuits used in the industry including diagnosis of common faults found in a specific practical application.	**M3** Conduct a detailed analysis of various types of lighting circuits, their practical industry applications, including diagnosis of common and less common faults.	**D3** Evaluate a broad spectrum of modern lighting circuits in practical application scenarios, with a focus on diagnosing, troubleshooting and proposing solutions for a range of serious faults.
LO4 Discuss the operating characteristics of electrical safety components including evaluation of their effectiveness through fault-finding techniques		
P4 Discuss the operating characteristics of commonly used electrical safety components. P5, Demonstrating the ability to evaluate the effectiveness of electrical components using simple fault-finding techniques.	**M4** Analyse the operating characteristics of a selection of electrical safety components and fault-finding scenarios in an industrial situation.	**D4** Critically analyse the operating characteristics of modern electrical safety components, using sophisticated fault-finding techniques, with strategies for improving safety component performance and reliability.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Boss M.J. and Norris G.M. (2015) *Electrical Safety: Systems, Sustainability, and Stewardship*. 1st Ed. CRC Press.

Cadena R. (2021) *Electricity for the Entertainment Electrician & Technician*. 3rd Ed. Routledge.

Fuchs E.F. and Masoum M.A.S. (2023) *Power Quality in Power Systems, Electrical Machines, and Power-Electronic Drives* (Paperback). Elsevier Science Publishing Co Inc.

Gill P. (2016) *Electrical Power Equipment Maintenance and Testing*. 2nd Ed. CRC Press.

Gonen T. (2014) *Electric Power Distribution Engineering*. 3rd Ed. CRC Press.

Guru B.S. and Hiziroglu H.R. (2001) *Electric Machinery and Transformers.* 3rd Ed. Oxford University Press.

Herman S.L. (2013) *Electric Motor Control.* 10th Ed. Cengage Learning.

Hughes A. and Brury B. (2019) *Electric Motors and Drives: Fundamentals, Types and Applications*. 5th Ed. Newnes.

Kitcher C. (2018) *Practical Guide to Inspection, Testing and Certification of Electrical Installations*. 4th Ed. Routledge.

Kumar J., Tripathy M. and Jena P. (Editors) (2023) *Control Applications in Modern Power Systems: Select Proceedings of EPREC 2021 − Lecture Notes in Electrical Engineering 870* (Paperback). Springer Verlag.

Maycock W.P. (2023) *Electric Lighting and Power Distribution: An Elementary Manual On Electrical Engineering, Suitable For Students Preparing For The Preliminary And Ordinary Grade Examinations Of The City And Guilds Of London Institute*; Volume 1 (Hardback). Legare Street Press.

Neitzel D.K. (2019), Capelli-Schellpfeffer M. and Winfield A. (2019) *Electrical Safety Handbook (ELECTRONICS) Hardcover.* McGraw Hill.

Olsen I. (2017*) Electrical Generation and Distribution Systems and Power Quality Disturbances* (Hardback). Scitus Academics LLC.

Ree J.M.P. (2022) *Lecture Notes on Electrical lighting illumination: Simplified Approach* (Paperback).

Taylor W.T. (2023) *Electric Power Systems: A Practical Treatment of the Main Conditions, Problems, Facts and Principles in the Installation and Operation of Modern Electric Power Systems, for System Operators, General Electrical Engineers and Students* (Paperback). Legare Street Press.

The Institution of Engineering and Technology. *BS 7671 − 18th Edition: The IET Wiring Regulations Information and help for electrical installers*.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

IEEE Industry Applications Magazine

IEEE Power and Energy Magazine

IEEE Sensors

IEEE Transactions on Power Systems

Journal of Electrical Systems

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4021: Electrical Machines

Unit 4022: Electronic Circuits and Devices.

Unit 4027: CAD for Schematics in Maintenance Engineering

Unit Code: Y/651/0898

Level: 4

Credits: 15

Introduction

There is a growing trend, in part due to the popularity of three-dimensional (3D) Computer Aided Design (CAD) systems, for students to generate two-dimensional (2D) drawings from three-dimensional (3D) solid models. 3D models do look impressive and whilst they clearly serve an important function in CAD design, in reality the vast majority of CAD drawings used in the industry are 2D based and, of those, a significant number are schematic drawings utilised by maintenance engineers, which cannot be produced using a 3D system.

The aim of this unit is to enable students to produce 2D CAD drawings (using industry standard CAD software), and to modify and construct electrical and mechanical drawings e.g., distribution systems, fire alarms, steam ranges, electrical and hydraulic circuits. This unit will support the development of the students' CAD abilities and build upon those skills to introduce the more advanced techniques that are used to create and modify schematic drawings quickly and efficiently. These techniques can be used to construct pre-prepared symbols for use in circuit diagrams or be used to create unique symbols and symbol libraries.

Alongside the creation of schematic drawings utilising the block, attributes and insert commands, the students will also learn how to extract information to populate spreadsheets and databases, tabulating the information directly from the working drawing.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Produce CAD drawings

LO2 Create blocks with textual attributes to perform insert and export operations

LO3 Construct complex schematic drawings

LO4 Transfer information to external sources.

Essential content

LO1 **Produce CAD drawings**

Introduction to the user interface:

Command line, Status Bar, panel titles and tabs

Recognise and apply absolute, relative and polar coordinates.

Drafting aids:

Grid, snap, object snap, ortho and polar tracking.

Draw commands:

Line types, circle, text, hatching, dimensioning.

Modifying commands:

Sketch commands, copy, rotate, move, erase, scale, array, chamfer, fillet

Creating and defining text and dimension styles.

Multiline and Single line text

Creating layers:

Layers/levels, colour, line thicknesses

Viewing commands:

Zoom, pan, viewports and layouts.

Case studies:

Industry relevant CAD examples relevant to maintenance engineers.

LO2 **Create blocks with textual attributes to perform insert and export operations**

Blocks and textual attributes:

Creating and editing blocks and write blocks

Defining, editing and managing attributes

Inserting blocks from external sources

Attribute extraction

Dynamic and nested blocks

Using the design centre and tool palettes.

LO3 **Construct complex schematic drawings**

Complex schematics:

Create block library and table legend, including symbols and description

Create electrical, electronic, hydraulic and pneumatic schematic drawings, Process Flow Diagrams (PFDs). Engineering Flow Diagrams (EFDs) and Vent Flow Diagrams (VFDs)

Industry case studies using complex schematic drawings and professional discussion on good practice observed.

LO4 **Transfer information to external sources.**

Electronic transfer of information:

Data extraction and data extraction (DXE) files, DWG/DXF files

Step-files ISO 10303-21

Extracting data to tables and spreadsheets

Organise and refine the extracted data

Table styles and formatting data extraction tables

Present CAD related work undertaken to peers or a team of maintenance engineers and respond to feedback.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Produce CAD drawings		
P1 Propose the range of drawing aids that assist productivity. **P2** For a given engineering maintenance context, produce a template file to include a range of layers, dimension styles, text styles, border and title box.	**M1** Contrast the advantages and disadvantages of using CAD over manual drafting in support of maintenance engineer role.	**D1** Evaluate the advantages of using template files.
LO2 Create blocks with textual attributes to perform insert and export operations		**LO2 and LO3**
P3 Create ten schematic symbols. **P4** Add appropriate attribute data to each of the schematic symbols and convert into blocks.	**M2** Justify the advantages of using blocks in a drawing.	**D2** Validate how using attributes can improve productivity.
LO3 Construct complex schematic drawings		
P5 Construct a block library and table legend and integrate into a template file. **P6** Create a complex schematic drawing using electrical/electronic or hydraulic symbols.	**M3** Describe the advantages of using block libraries and how they can enhance templates.	
LO4 Transfer information to external sources		
P7 Transfer attribute data to Excel spreadsheets. **P8** Explain the advantages of using data extraction (i.e., DXE, DWG, DXF) files.	**M4** Appraise the process for extracting drawing data to create a table.	**D3** Assess how electronic transfer of information can aid productivity, with example engineering maintenance applications.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bi Z. and WANG X. (2020) *Computer Aided Design and Manufacturing*. Wiley.

BS 8888 (2017) *Technical product documentation and specification*.

Metwalli S.M. (2021) *Machine Design with CAD and Optimization*. Wiley.

Omura G. and Benton B.C. (2014) *Mastering AutoCAD 2015 and AutoCAD LT 2015 Essentials*. Autodesk Official Press

Pitroda H. P (2019) *Computer Aided Design: Textbook and Practice book*. Walnut publication

Sarkar J., (2014). *Computer aided design: a conceptual approach*. CRC Press.

Shih R.H. (2024) *Principles and Practice: An Integrated Approach to Engineering Graphics and AutoCAD 2024*. 1st Ed. SDC Publications.

Simmons C.H., Dennis E. and Maguire N.P. (2020) *Manual of Engineering Drawing – British and International Standards.* 5th Ed. Butterworth-Heinemann.

Stark J. (2021) *What Every Engineer Should Know about Practical CAD/CAM Applications.* CRC Press.

Zeus Precision Charts Ltd. *Zeus Precision Data Charts and Reference Tables for Drawing Office, Toolroom & Workshop*.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

CAD Journal – CAD and Applications

Computer-Aided Design

Computer-Aided Design and Applications

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4023: Computer Aided Design and Manufacture (CAD/CAM)

Unit 4034: Computer Aided Design (CAD) for Engineering.

Unit 4028: Materials Engineering with Polymers

Unit Code: T/651/0751

Level: 4

Credits: 15

Introduction

This unit will provide students with the necessary background knowledge and understanding of the structure and property relationship of polymer materials to guide their selection of material and manufacturing techniques to produce a sustainable, fit for purpose product.

Polymer products are driving innovation and research around the world and are predicted to expand further to replace traditional engineering materials in a wide variety of applications. Students will be made aware of the wide range of polymer materials at their disposal and the opportunity for using the new grades that are being developed on a daily basis.

This unit will provide students with an understanding of the relationship between a polymer’s structure and properties and between processing technique and product performance. The ability to determine a polymer’s properties is crucial and this unit will include a review and practical application of the main testing techniques. One of the most important skills for a manufacturing engineer is the ability to distinguish between different types of polymers. This will be developed during practical sessions that will provide students with the opportunity to carry out preliminary investigations and simple identification tests. This will be supported by an overview of the main types of polymer materials.

Inadequate consideration of a specific behavioural requirement can lead to product failure and reduced service life. This will be addressed by providing techniques for material modification and learning how to use data sources for material selection. In addition this unit will consider environmental concerns and offer solutions to reduce waste and improve sustainability.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties

LO2 Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application

LO3 Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application

LO4 Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers.

Essential Content

LO1 **Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties**

Introduction:

Polymer concept

Definition of the main terms, e.g. monomer, repeating units

Classification of polymers (natural, synthetic, organic, inorganic).

Molecular Structure:

Structure of polyethylene chain

Chain length and molar mass;

Molar mass distribution;

Calculations of number (average molar mass and weight-average molar mass)

Significance of molar mass to processing and performance properties of polymers

Configuration of the chain molecule

Confirmation of the chain molecule

Secondary bonds between chain molecules

Cohesion

Adhesion

Solubility

Compatibility of polymer blends.

Polymer morphology:

Aggregational states of matter

Amorphous solid state

Amorphous polymers

Glass transition temperature and its significance to processing and service life crystalline polymers

Melting temperature, conditions for crystallinity, effect of processing on crystallinity, morphological features (lamellae and spherulites).

LO2 **Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application**

Commodity and engineering thermoplastics:

E.g. polyethylenes

Modified polyethylenes; polypropylene

Polyamides and aramids (overview of structure, properties and processability).

Thermosets:

E.g. epoxies

Phenolics; polyesthers

Material storage

Concept of gel-point

Quantitative analysis i of cross-linking (overview of structure, properties and processability).

Rubber and elastomers:

E.g. natural rubber (NR)

Acrylonitlile butadiene rubber (NBR); styrene butadiene rubber (SBR), butyl rubber (BR), polychloroprene rubber (CR), ethylene propylene rubber (EPR)

Introduction to vulcanisation and compounding

Overview of structure, properties and processability.

Introduction to simple identification tests and techniques:

E.g. density, solubility.

LO3 **Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application**

Criteria for material selection:

Definitions of material properties and characteristics

Material selection flow chart

Overview of selection methods e.g. structured and unstructured data; material selection charts.

Material testing to determine the properties of polymers

Mechanical e.g. tensile, flexural, impact

Optical (colour)

Electrical (conductivity/resistivity)

Thermal (melting temperature, glass transition temperature)

Rheological.

Data sources:

Published data e.g. British standards, ISO, material's data sheet, IT sources, standard published data sources, manufacturers' literature

Assessment of data reliability.

Polymer modification:

Review of polymer additives and their functions

Consideration of their cost and quantity in a compound formulation e.g. fillers, plasticisers, stabilisers, flame retardants, blowing agents, colourants, cross-linking and vulcanising agents.

LO4 **Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers.**

Premature failure of polymer products:

Causes of failure in polymer products e.g. visco-elastic and time-dependent behaviour of polymers, brittle and ductile failure, impact failure, creep rupture and fatigue failure, environmental effects

Contributory effects of service conditions to failure e.g. faults in design and manufacture, inappropriate use, changes to service conditions such as load, time, temperature and environment.

Solutions to environmental concerns:

Overview of relevant Government policies and Directives

Acceptable waste management and disposal techniques e.g. re-use, mechanical recycling of single and mixed polymers

Feedstock recycling to produce monomers, oligomers and chemical raw materials energy recovery

Re-processing of polymers and its effect on processing and mechanical properties stabilisation of polymers to prevent weathering, chemical and thermal degradation.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties</td><td rowspan="4">LO1 and LO2
D1 Justify the selection of a polymer material for a given engineering application through critical analysis of its structure and properties.</td></tr>
<tr><td>P1 Explain how the structure and morphology of different given polymer materials affect their processing and performance properties.</td><td>M1 Calculate the molar mass of a given polymer sample, commenting on the significance of the results to processing and performance properties.</td></tr>
<tr><td colspan="2">LO2 Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application</td></tr>
<tr><td>P2 Use preliminary investigations and simple identification tests to distinguish between different types of polymer materials.</td><td>M2 Apply structural considerations to compare and contrast the properties and processability of these polymer materials.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application		**LO3 and LO4**
P3 Identify the required properties for a specified engineering product. **P4** Evaluate data sheets to select the most appropriate materials and processing techniques for the engineering product.	**M3** Re-examine data sheets to extend the range of selected materials by proposing a suitable modification to the base material.	**D2** Critically evaluate test results to justify selection of the most suitable additive or acceptable amount of recycled material in a given product.
LO4 Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers.		
P5 Explain the common causes of premature failure of polymer products. **P6** Explain how polymer materials can be safely disposed or recovered through acceptable waste management techniques.	**M4** Give consideration to the contributory effects of service conditions in a given product and make recommendations to prevent failure. **M5** For a given product/evaluate the potential benefit of using recycled material in place of virgin material.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby, M.F. and Jones, D.R.H. (2013) *Engineering Materials 2: An Introduction to Microstructures and Processing*. 4th Ed. Amsterdam: Butterworth-Heinemann.

Ashby, M.F. and jones, D.R.H. (2012) *Engineering Materials 1: An Introduction to Properties, Applications, and Design*. 4th Ed. Amsterdam-Boston: Butterworth-Heinemann.

Braun, D. (2013) *Simple Methods for Identification of Plastics*. 5th Ed. Munich: Hanser.

Callister, W. and Rethwisch, D.G. (2015) *Fundamentals of Materials Science and Engineering: An Integrated Approach*. 5th Ed. Hoboken: Wiley.

Fried J.R. (2014) *Polymer science and technology.* 3rd Ed. Pearson.

Guo Q. (2016) *Polymer Morphology: Principles, Characterization, and Processing*. Wiley.

La Mantia, F. (2002) *Handbook of Plastics Recycling*. Shrewsbury: Rapra Technology Limited.

McCrum, N.G., Buckley, C.P. and Bucknall, C.B. (2003*) Principles of Polymer Engineering*. 2nd Ed. Oxford: Oxford. Univ. Press.

Osswald, T.A. and Menges, G. (2012) *Material Science of Polymers for Engineers*. 3rd Ed. Munich: Hanser.

Young, R.J. and Lovell, P.A. (2011) *Introduction to Polymers*. Boca Raton: CRC Press.

Websites

www.bpf.co.uk	British Plastics Federation (General reference)
www.iom3.org/polymer-society	The Polymer Society (General reference)
www.cia.org.uk	Chemical Industries Association (General reference)
www.cogent-ssc.com	Cogent – Sector Skills Council (General reference)
www.stemnet.org.uk	Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme (General reference)

Essential Resources

Tensometer (to evaluate tensile properties of materials, such as Young’s modulus)

Pendulum impact tester

Hardness tester

Controlled laboratory area for flammable tests on polymers

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4009: Materials, Properties and Testing

Unit 4069: Properties and Applications of Materials and Emerging Materials Pre-Production.

Unit 4029: Polymer Manufacturing Processes

Unit Code: A/651/0753

Level: 4

Credits: 15

Introduction

This unit is designed to develop students' knowledge and understanding of the main manufacturing processes and techniques that can be applied to a wide range of polymer materials for a variety of manufacturing applications.

It is essential for a manufacturing engineer who may lead the planning, operation and management of their company's manufacturing systems to have a broad underpinning knowledge of conventional polymer manufacturing processes. Polymer materials have the capacity and potential to be processed into a huge variety of shapes and forms for a wide range of applications.

The first outcome of this unit provides background knowledge of the main principles of polymer flow and heat transfer relevant to processing. The second and third outcomes give a detailed overview of the conventional manufacturing techniques of polymers (extrusion, blow moulding, thermoforming and injection moulding) considering relevant equipment and processing steps. The final outcome provides the context to inform selection of the most suitable method of processing for a given application.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Relate the fundamental principles of polymer flow and heat transfer to polymer processing

LO2 Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products

LO3 Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps

LO4 Determine from a design perspective the most suitable manufacturing process for a given engineering component or product.

Essential Content

LO1 Relate the fundamental principles of polymer flow and heat transfer to polymer processing

Polymer melt behaviour:

Elongational flow

Shear flow

Shear stress and shear strain

Determination of apparent viscosity

Dependence of apparent viscosity on temperature and relative molecular mass

Shear thinning behaviour of polymers

Viscoelasticity of polymer melt

Die swell

Flow in a capillary tube (equations for stress and shear rate)

Melt flow index test (MFI).

Effect of heating and heat transfer in polymers:

Temperature-dependent behaviour of polymers

Conduction (heat conduction equation, thermal conductivity, thermal diffusivity) convection

Radiation

Comparison of heat transfer properties of polymers to other competitive materials e.g. Metals, ceramics, wood.

LO2 Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products

Overview of processing techniques for thermoplastics:

Extrusion e.g. Sheet production, pipe production, blown film, wire and cable coating, co-extrusion

Injection moulding, injection blow moulding

Rotational moulding

Thermoforming

Consideration of materials and products.

Overview of processing techniques for thermosets:

E.g. Compression moulding and injection moulding

Specific requirements to process thermosets

Consideration of materials and products.

Overview of shaping and processing techniques for rubber and elastomers:

E.g. Extrusion, compression moulding and injection moulding

Compounding principle

Consideration of materials and products.

LO3 **Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps**

Extrusion:

The principle of the extrusion process

Extrusion line

Main components of extruder and their functions e.g. Hopper, screw, motor and gearing, breaker plate and screen pack, die, temperature control system

Single and twin-screw extruders

Die design and processing faults.

Injection moulding:

The principle of the injection moulding process

Components of injection moulding machine and their functions e.g. Clamping unit, injection unit, mould, machine bed and control unit

Process sequence

Common injection moulding faults and remedies.

Thermoforming:

The principle of the thermoforming process

Process components e.g. Clamp frame, heating systems, moulds

Selected thermoforming methods e.g. Female mould forming, male mould forming, plug assist forming, prestretch forming

Wall thickness and molecular orientation in thermoformed products.

LO4 **Determine from a design perspective the most suitable manufacturing process for a given engineering component or product.**

Design consideration and application development process:

Identifying the end-use requirements after considering the product functions

Part geometry e.g shape, size, tolerances

Material selection

Flow analysis and the significant implications of process selection stage

Prototyping and testing.

Design for mouldabilty:

E.g. Viscosity, melt temperature, shrinkage, cooling requirements, selection of optimum processing conditions.

Tooling consideration:

Design for appearance e.g. Preventing weld lines, gate marks in injection moulded components

Design for precision e.g. Gate location, gate type, gate size, die design, cooling lines.

Consideration of production volumes and cost of manufacturing:

Relevant case studies.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Relate the fundamental principles of polymer flow and heat transfer to polymer processing</td><td rowspan="4">LO1 and LO2

D1 Critically evaluate the effects of temperature and relative molecular mass on viscosity and processing.</td></tr>
<tr><td>P1 Explain the differences between the types of flow apparent in polymer melt and their relevance to processing.

P2 Explain the difference in heat transfer between polymers and alternative materials and the effect it has on processing.</td><td>M1 Calculate polymer flow and heat transfer parameters for different grades of a thermoplastic material, commenting on the significance of the results for polymer processing.</td></tr>
<tr><td colspan="2">LO2 Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products</td></tr>
<tr><td>P3 Describe a manufacturing set-up for given products and materials.</td><td>M2 Compare and contrast a range of alternative processing and shaping techniques for a given product/application.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps		
P4 Define the main differences between extrusion, injection moulding and thermoforming in terms of their components, functions and process sequence.	**M3** Analyse potential process-related faults for a given product or application.	**D2** Justify the most suitable manufacturing process for a given engineering product.
LO4 Determine from a design perspective the most suitable manufacturing process for a given engineering component or product.		
P5 Determine functions, shape and material for a given component/product and recommend the most appropriate manufacturing process based on the component's or product's functions, shape and material.	**M4** Justify specific tooling for a given component or product.	**D3** Critically evaluate the cost-effectiveness of the selected manufacturing process.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Baird, D.G. and Collias, D.I. (2014) *Polymer Processing: Principles and Design*. 2nd Ed. New Jersey: Wiley.

Lee, N.C. (2007) *Understanding Blow Molding*. 2nd Ed. Munich: Hanser.

Kaynak A. and zolfagharian A. (2019) *Stimuli-Responsive Polymer Systems – Recent Manufacturing Techniques and Applications.* MDPI Books.

Osswald, T.A. (2011) *Understanding Polymer Processing: Processes and Governing Equations*. Munich: Hanser Publishers.

Rao, N.S. and Schumacher, G. (2004) *Design Formulas for Plastics Engineers*. Munich: Hanser.

Rauwendaal, C. (2014) *Polymer Extrusion*. 5th Ed. Munich: Hanser Publications.

Throne, J.L. (2008) *Understanding Thermoforming*. 2nd Ed. Munich: Hanser.

Websites

www.bpf.co.uk	British Plastics Federation (General reference)
www.iom3.org/polymer-society	The Polymer Society (General reference)
www.cia.org.uk	Chemical Industries Association (General reference)
www.cogent-ssc.com	Cogent – Sector Skills Council (General reference)
www.stemnet.org.uk	Network for Science, Technology, Engineering and Maths – Network Ambassadors Scheme (General reference)

Essential Resources

Laboratory Micro Injection Moulder Filament Extrusion line

Vacuum former

Melt Flow tester

Laboratory balance

Links

This unit links to the following related units:

Unit 4008: Materials Engineering with Polymers

Unit 4030: Industry 4.0

Unit Code: F/651/0755

Level: 4

Credits: 15

Introduction

Industry 4.0 is the term that has been adopted to describe the 'fourth' industrial revolution currently underway, at present, in the manufacturing and commercial sectors of our society. It is a revolution based on the integration of cyber-physical systems, Internet of Things, Big data, 3D printing, advanced robotics, simulation, augmented reality, cloud computing and cyber security. Industry 4.0 is changing the way the world's most successful companies produce the products that their global customers demand. For the engineering and manufacturing sector, this integration has been enabled by successfully combining high performance computing, the internet and the development of advanced manufacturing technologies and highly flexible and adaptive manufacturing processes.

The aim of this unit is to provide holistic understanding of industry 4.0 and current trends of the production, assembly and other key aspects modern manufacturing. Students are first introduced to the background and fundamental and historical concepts of the fourth industrial revolution and principles, technologies, and strategies driving it. Students will then explore cutting-edge technologies, such as the Industrial Internet of Things (IIoT), cyber-physical production systems (CPPS) and artificial intelligence, and learn how these innovations are transforming traditional manufacturing processes and business models. Students are expected to reflect on successful case studies of transitioning to Industry 4.0 and communicate the industry 4.0 concepts, technologies, and implications.

On successful completion of this unit students will be able to investigate and evaluate industrial revolutions along with the characteristics and real-world challenges. As potential managers, students will also be able to

assess the transformation of supply chains, business models, and workforce dynamics in the context of Industry 4.0 and associated benefits.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Discuss the key concepts and principles of Industry 4.0

LO2 Review the range of cyber-physical production systems (CPPS) shaping Industry 4.0 and their integration with the Industrial Internet of Things (IIoT)

LO3 Explore the implications and impacts of Industry 4.0 in engineering and manufacturing processes and technologies

LO4 Examine the factors manufacturers need to consider when transitioning to Industry 4.0 and workforce Implications.

Essential Content

LO1 **Discuss the key concepts and principles of Industry 4.0**

Industrial revolution:

Industry 4.0 historical context: changes from Industry 1.0 to Industry 4.0 and future trends (e.g. Industry 5.0); analogous terms (e.g., Space 4.0, Agriculture 4.0, Maritime 4.0, Mining 4.0, Medical 4.0 etc.)

Fundamental concepts and characterisations

Design for service (DFS), Design for Assembly (DfA) and Design for Manufacturing (DfM) in the age of industry 4.Design Failure Mode and Effect Analysis (DFMEA)

Technology drivers: IoT, IIoT, Artificial Intelligence (AI), cloud computing and automation; integration of digital technologies, data and automation

Areas of impact and applications: For example, − workforce, skills, efficiency, change management; applications in energy, automotive, health and pharma, Agrifood, transportation, social mobility, business, science and technology, communications, geography etc.

Case studies: Example smart factory − connectivity, scalability, autonomy, agility, efficiency, voice-controlled user interfaces.

LO2 **Review the range of cyber-physical production systems (CPPS) shaping Industry 4.0 and their integration with the Industrial Internet of Things (IIoT)**

Definitions, characteristics, and architecture

Interconnected systems enabled by the IoT and cloud computing

Components of CPPS: sensors/smart sensors, actuators and communication protocols including wireless protocols e.g. WiFi, Bluetooth, Zigbee, MQTT, cellular, data, Z-Wave, near-field communication (NFC)

Data in Industry 4.0: data collection systems, data formats and storage, database solutions, data visualisation, forecasting, quality control, data-driven decision-making; data analytics – big data, types including streaming, spatial, time series, prescriptive, predictive, and decisive analytics.

Cloud computing and Industry 4.0: Types (SaaS, IaaS, PaaS); uses with IoT/IIoT; developments such as industrial edge computing, communication protocols and data protection.

Flow diagram of data/information transfer in the cloud

Blockchain technology applications for Industry 4.0

Threats, vulnerabilities, and risk mitigation

Data protection, privacy and compliance.

LO3 **Explore the implications and impacts of Industry 4.0 in engineering and manufacturing processes and technologies**

Robotics and automation in modern manufacturing:

Collaborative, programmable robots and autonomous systems

AI driven decision making and optimisation

Importance of 3D Printing in Industry 4.0

Concept and applications of Digital Twins for manufacturing

Applications of Augmented and Virtual Reality in manufacturing, relevant development/usage platforms (e.g., HoloLens, Metaverse)

Data-Driven Manufacturing

Process mining – types, tools, sector wide examples.

LO4 **Examine the factors manufacturers need to consider when transitioning to Industry 4.0 and workforce Implications**

Standardisation of technologies:

Application interfaces, Integration points and Automation technologies.

Transforming Operational Processes:

Digital Transformation, Merge OT with IT, Worker Mobility, Intelligent Machine Applications.

Transforming Business Models:

New Digital Business, Industrial Analytics, Identify and procure suitable resources including finance, supplies, tools and equipment; role of stakeholders; Supplier, manufacturer, and customer integration.

Transform the Workforce:

Support and training for the workforce, safe and professional working practices, ethical and social considerations, legislative requirements, functional safety standards and application (IEC 61508, IEC 61511, IEC 62061, ISO 10218, IEC 61784, EN 50159, IEC 62280, IEC 62443), environment and sustainability considerations.

Safety first culture within the context:

Health and safety policies, procedures and regulations, compliance,
risk assessment and mitigation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss the key concepts and principles of Industry 4.0		
P1 Discuss the key milestones of industrial revolutions leading to the Industry 4.0. **P2** Describe any two example areas of impacts for Industry 4.0 in a chosen sector of engineering and manufacturing.	**M1** Analyse two different use cases for the main technology drivers of Industry 4.0. **M2** Explore the implications of DFMEA in the context of Industry 4.0.	**D1** Evaluate the application areas, wider impact and threats of Industry 4.0.
LO2 Review the range of cyber-physical production systems (CPPS) shaping Industry 4.0 and their integration with the Industrial Internet of Things (IIoT)		
P3 Review the relationship between cyber-physical production systems (CPPS) and the Internet of Things (IoT). **P4** Explore a program plan for the IOT and a range of wireless communication protocols available for the smart factory.	**M3** Analyse the principles and benefits of cloud computing and its role with suppliers, manufacturers, and customers within Industry 4.0 for an example case study. **M4** Investigate the risk mitigation strategies for the treats and vulnerabilities of cyber physical systems within a case study.	**D2** Evaluate a case study design of cyber-physical systems architecture with complete process flow for Industry 4.0 based manufacturing systems.
LO3 Explore the implications and impacts of Industry 4.0 in engineering and manufacturing processes and technologies		
P5 Examine the process flow for the design of data-driven manufacturing. **P6** Explore Process mining within a given engineering/ manufacturing sector.	**M5** Explore the role of robotics and automation in modern production and manufacturing.	**D3** Demonstrate the application and benefits of digital twinning for Industry 4.0 manufacturing.
LO4 Examine the factors manufacturers need to consider when transitioning to Industry 4.0 and workforce Implications		
P7 Examine the key principles of operational process transformation to Industry 4.0. **P8** Explore the safety requirements and standards for transition to Industry 4.0.	**M6** Analyse the potential skills required by the Industry 4.0 workforce to enable effective transition.	**D4** Critique the digital business models within Industry 4.0 for agile transition.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

André J. (2019) *Industry 4.0: Paradoxes and Conflicts.* Wiley.

Bali V., Bhatnagar V., Aggarwal D., Bali S., and Diván M. J. (2021) *Cyber-Physical, IoT, and Autonomous Systems in Industry 4.0.* CRC Press.

Barkai, J. (2016) *The Outcome Economy: How the Industrial Internet of Things is Transforming Everyday Business*. CreateSpace Independent Publishing Platform.

Elanqovan U. (2023) *Industry 5.0 The Future of the Industrial Economy.* 1st Ed. CRC Press.

Frenz W. (2022) *Handbook Industry 4.0.* Springer.

Hassoun A. (2024) *Food Industry 4.0.* 1st Ed. Elsevier.

Kandasamy J., Muduli K., Kommula V. P., and Meena P. L. (2023) *Smart Manufacturing Technologies For Industry 4.0 Integration, Benefits, and Operational Activities.* CRC PRESS.

Massaro A. (2021) *Electronics in Advanced Research Industries: Industry 4.0 to Industry 5.0 Advances.* Wiley.

Mavropoulos A. and Nilsen A.W. (2020) *Industry 4.0 and Circular Economy: Towards a Wasteless Future or a Wasteful Planet?* Wiley.

Sharifzadeh M. (2022) *Industry 4.0 Vision for the Supply of Energy and Materials: Enabling Technologies and Emerging Applications.* Wiley.

Sullivan M. and Kern J. (2021) *The Digital Transformation of Logistics: Demystifying Impacts of the Fourth Industrial Revolution.* Wiley.

Tromp J.G., Le D. and Le C.V. (2020) *Emerging Extended Reality Technologies for Industry 4.0: Early Experiences with Conception, Design, Implementation, Evaluation and Deployment.* Wiley.

Vasant P., Munapo E., Thomas J.J., and Weber G. (2022) *Artificial Intelligence in Industry 4.0 and 5G Technology.* Wiley.

Windpassinger, N. (2017) *Digitize or Die: Transform your Organisation, Embrace the Digital Evolution, Rise above the Competition*. New York: IoT Hub.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Manufacturing Letters

Cogent Engineering

Complex and Intelligent systems

Industry 4.0 Clustering of Concepts and Characteristics

New Frontiers in Industry 4.0

Procedia Manufacturing

Links

This unit links to the following related units:

Unit 4068: Industrial Robots

Unit 4085: Mechatronic Systems in Manufacturing

Unit 5017: Advanced Manufacturing Technology

Unit 4031: Introduction to Professional Engineering Management

Unit Code: J/651/0757

Level: 4

Credits: 15

Introduction

Engineers design, develop, manufacture, construct, operate and maintain the physical infrastructure and content of the human society we inhabit. The responsibilities that engineers bear for the safety of the people who use the outputs of their work, and the environment in which they operate, are enormous. Engineers must adopt a professional approach to their work, personal development and relationship with society and the environment.

This unit introduces students to the roles, responsibilities and behaviours of professional engineers, including the ethical and regulatory frameworks that exist to support and guide their work to maintain published standards.

Methods of personal and professional development will be examined, as will the role of reflection for learning and practice, the cycle of reflection and the importance of reflective writing in the process of development. The student will also be introduced to engineering and people management tools, together with the importance of effective communication techniques.

On successful completion of this unit the student will understand the demands of being a professional engineer and be able to construct a personal development plan for their career that meets the required standards for their role and the environment in which they operate.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the role of the professional engineer and the ethical and regulatory codes that govern this role

LO2 Demonstrate effective leadership and communication skills

LO3 Explore the importance of social responsibility when developing personal and professional standards in manufacturing organisations

LO4 Review the role of reflection, appropriate to the work of a professional engineer.

Essential Content

LO1 **Describe the role of the professional engineer and the ethical and regulatory codes that govern this role**

The role of the professional engineer:

Roles and levels of responsibility

The professional framework

Role of Chartered Engineer

Roles of Incorporated Engineer and Engineering Technician

Function of professional bodies and the Engineering Council

Legal and ethical responsibilities

Consequences of failure.

Ethical frameworks:

The Engineering Council and Royal Academy of Engineering's Statement of Ethical Principles

The National Society for Professional Engineers' Code of Ethics.

Regulatory bodies:

Global, European and national influences on engineering and the role of the engineer, in particular: the Royal Academy of Engineering and the UK Engineering Council

Role and responsibilities of the UK Engineering Council and the professional engineering institutions (PEIs)

Content of the UK Standard for Professional Engineering Competence (UKSPEC)

Regulation of the roles of Chartered Engineer, Incorporated Engineer and Engineering Technician.

International regulatory regimes and agreements:

European Federation of International Engineering Institutions

European Engineer (Eur Ing)

European Network for Accreditation of Engineering Education

European Society for Engineering Education

Washington Accord

Dublin Accord

Sydney Accord

International Engineers' Alliance

Asia Pacific Economic Cooperation (APEC) Engineers' Agreement.

LO2 **Demonstrate effective leadership and communication skills**

Leadership:

Leadership styles, and their effectiveness and appropriateness

Organisational ethos and culture; commitment to equality and diversity

Managing teams; participation and feedback; negotiation; human error evaluation; setting up support structures for team members; appropriateness of coaching and mentoring.

Communication skills:

Listening, non-verbal communication, clarity and brevity, friendliness, confidence, empathy, open-mindedness, respect, feedback and picking the right medium.

Communication with groups:

Group expectations; dealing with reactions and disagreements; allowing and encouraging participation; acting on agreed outcomes; negative communication; motivating disillusioned colleagues; persuasion and negotiation.

Equality and diversity

Ensuring work produced and the approach to work is inclusive and takes proper account of equality of opportunity and the diverse nature of the population.

LO3 **Explore the importance of social responsibility when developing personal and professional standards in manufacturing organisations**

Becoming a professional engineer:

Social responsibility in the engineering profession

Importance of being active and up to date with the engineering profession, new developments and discoveries

Methods of Continuing Professional Development (CPD)

Creating and managing a career plan.

LO4 **Review the role of reflection, appropriate to the work of a professional engineer.**

Reflection for learning:

The difference between reflection and evaluation

Reflection for learning.

The cycle of reflection:

Reflection in action and reflection on action

How to use reflection to inform future behaviour, particularly with respect to sustainable performance.

Reflective writing:

Writing as a reflective process

The difference between a reflective log and a diary; importance of creating and regularly completing a reflective log

Avoiding generalisation and focusing on personal development and the research journey in a critical and objective way.

Continuing professional development (CPD):

The role of the reflective log in informing and driving CPD

Employee and employer benefits of CPD

Peer review; receiving and giving

The role of the engineering institutes in CPD

CPD planning and refining

CPD opportunities, e.g. workshops, site visits, lectures, short courses.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the role of the professional engineer and the ethical and regulatory codes that govern this role		
P1 Describe the roles and responsibilities of the professional engineer within the Engineering Councils framework. **P2** Identify the principal UK codes and regulations which control the work of the professional engineer.	**M1** Analyse the main areas of influence exercised by the professional bodies in the UK on the work of the professional engineer.	**D1** Evaluate the effect of ethical frameworks on the day-to-day work of a professional engineer.
LO2 Demonstrate effective leadership and communication skills		
P3 Demonstrate the process for effective persuasion and negotiation. **P4** Outline the steps for managing effective group communications.	**M2** Analyse leadership styles and effective communication skills using specific examples in an organisational context.	**D2** Evaluate the most effective methods for coaching and mentoring disillusioned colleagues or a poorly performing team.
LO3 Explore the importance of social responsibility when developing personal and professional standards in manufacturing organisations		**LO3 and LO4**
P5 Describe how social responsibility in engineering can support development in manufacturing. **P6** Outline the ways in which a professional engineer can remain up to date with new developments and discoveries.	**M3** Analyse the ethical standards and patterns of behaviour that apply to the engineering profession.	**D3** Evaluate the role of a socially responsible engineer and how the engineer can draw on a range of continuing professional development (CPD) opportunities.
LO4 Review the role of reflection, appropriate to the work of a professional engineer.		
P7 Undertake the completion of a reflective log. **P8** Review the 'cycle of reflection' and its role in the effective completion of a reflective log.	**M4** Analyse the benefits of continuing professional development from an employee and an employer perspective.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Burke R. (2013) Project management: planning and control techniques. 5th Ed. Wiley.

Dearden, H. (2013) *Professional Engineering Practice: Reflections on the Role of the Professional Engineer*. Scotts Valley: CreateSpace Independent Publishing Platform.

Karten, N. (2010) *Presentation Skills for Technical Professionals*. Cambridge: IT Governance.

Meredith J.R., Shafer S.M, Mantel Jr S.J., and Sutton M. M. (2020) *Project Management in Practice.* 7th Ed. Wiley.

Meredith J. (2015) *Project management: a managerial approach*. 9th Ed. Wiley.

Siegel G. N. (2019) *Engineering project management*. Wiley.

Websites

www.engc.org.uk	Engineering Council UK-SPEC – UK Standard for Professional Engineering Competence (General reference)
www.ewb-uk.org	Engineering without Borders Becoming a Professional Engineer (General reference)

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 5002: Professional Engineering Management.

Unit 4032: Introduction to Biomedical Engineering

Unit Code: D/650/9512

Level: 4

Credits: 15

Introduction

Biomedical engineering is an interdisciplinary field concerned with the application of knowledge and principles from engineering, physical and computer sciences to solve biological, medical and clinical problems and challenges. This rapidly evolving and expanding discipline has resulted in the development of revolutionary technologies that have allowed us to better understand, optimise and enhance the functions of biological and medical systems, such as the development of diagnostic technologies, imaging technologies, prosthetic devices, artificial implants and rehabilitative devices.

The purpose of this unit is to introduce the scope of biomedical engineering and its role in advancing healthcare. The unit will focus on applications of biomedical engineering in the fields of medical devices and equipment, robotics, medical instrumentation and sensors, and biomaterials and tissue engineering. It will introduce the use of laboratory techniques and equipment used in the field and provide an overview of their application in health and clinical care and research. The unit will also cover important ethical considerations, including patient safety and privacy, and regulatory frameworks and standards that govern the development and use of healthcare technologies in research and practice. The unit will end with a discussion of current and emerging trends and areas of research and innovation.

On successful completion of this unit students will be able to explain the role and scope of biomedical engineering and outline and present examples of its use in understanding, evaluating and optimising the functions of biological or medical systems. They will develop basic proficiency in obtaining and interpreting measurements using biomedical instruments and devices and will consider ethical and regulatory frameworks in the development and use of biomedical engineering technologies in research and practice.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Describe the scope of biomedical engineering and its application to biological and medical systems

LO2 Analyse biomedical data obtained using biomedical measurement equipment in a laboratory environment

LO3 Examine ethical and regulatory considerations in the development and use of biomedical technologies

LO4 Discuss emerging trends and the outlook for biomedical engineering.

Essential Content

LO1 **Describe the scope of biomedical engineering and its application to biological and medical systems**

Definition and scope of biomedical engineering:

Definition of biomedical engineering and contributing disciplines

Range and scope of biomedical engineering applications

Historical and current impact of biomedical engineering on healthcare

Case studies of technology-driven transformations/innovations in healthcare.

Biomedical engineering subspecialisations:

Biomedical instrumentation and sensors

Medical devices and robotics

Medical imaging

Prosthetics, orthotics and rehabilitative devices

Biomaterials and tissue engineering.

Role of the biomedical engineer:

Breadth of career pathways and opportunities in biomedical engineering

Professional societies and resources for biomedical engineers

Role of the biomedical engineer in industry, healthcare and academia.

LO2 **Analyse biomedical data obtained using biomedical measurement equipment in a laboratory environment**

Acquiring and assessing the performance of biomedical and healthcare equipment:

Installation and procurement

Testing, servicing and maintenance

Planned preventative maintenance

Limitations of equipment, identifying faults and conducting safety checks

Technical reports, instructions for use and documentation.

Introduction to biomedical data measurement:

Overview of biomedical data types e.g. heart rate, electrocardiograph (ECG), pulmonary function, imaging

Data acquisition principles and measurement techniques

Medical instruments and sensors.

Evaluation of data quality:

Concepts of calibration, accuracy, reliability, repeatability, linearity, sensitivity, range and hysteresis.

Data interpretation:

Limitations and appropriate use of measurement tools

Signal processing and concepts of filtering, noise and signal artefact

Basic descriptive statistics: intraindividual and interindividual means and variance

Errors of measurement.

Data presentation:

Graphical presentation and representation of data.

LO3 **Examine ethical and regulatory considerations in the development and use of biomedical technologies**

Use of biomedical and healthcare technologies:

Processes in acquiring approval for purchase, installation and use of technologies in clinical spaces

Safety in clinical spaces

Life expectancy of medical equipment

Disposal of out of service medical devices

Healthcare equipment safety checks and reporting/recording faults

Awareness initiatives/campaigns e.g. advancements in medical devices and usage, interventions to meet local needs

Marketing, sales and stakeholder relationship management.

Ethical principles and frameworks:

Introduction to ethical considerations in biomedical engineering research and practice

Ethical processes and considerations

Animal and human participant clinical trial testing, regulatory approvals required, ethics cttee approval, local approval from cttee for new interventional procedures, participant informed consent

Conflict of interest and disclosure.

Regulatory bodies:

Importance of following Health and Safety guidance and carrying it out thorough appropriate risk assessments

Global, European and national regulatory frameworks governing the development and use of biomedical technologies and research practice.

LO4 **Discuss emerging trends and the outlook for biomedical engineering**

Trends and advancements in biomedical engineering:

Emerging areas in research and innovation

Artificial intelligence (AI), machine learning and data analytics

Personalised medicine and targeted therapy.

Skills and behaviours in the biomedical industry:

Entrepreneurship and leadership in the biomedical sector

Grand challenges and example case studies

Professional responsibilities towards patients, service users, other stakeholders and society in general

The engineer in society.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the scope of biomedical engineering and its application to biological and medical systems		
P1 Describe the breadth of biomedical engineering and the interaction between the disciplines contributing to the field. **P2** Explore the range of biomedical engineering innovations and technologies in healthcare/clinical/academia settings at a global or national scale.	**M1** Assess the impact of biomedical engineering advances on current practice in healthcare and clinical settings and/or academia.	**D1** Illustrate with examples, applications of biomedical engineering in diagnosis and treatment of patients.
LO2 Analyse biomedical data obtained using biomedical measurement equipment in a laboratory environment		
P3 Prepare laboratory space and equipment for collection of physiological or other biomedical data. **P4** Demonstrate safe usage of biomedical equipment to measure physiological data. **P5** Analyse data for appropriate evaluation and use of correct units.	**M2** Analyse biomedical data and analysis techniques in research and clinical practice. **M3** Produce appropriate graphical visualisations of biomedical data.	**D2** Evaluate data obtained from measurements, considering limitations of equipment and data quality measures.

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Examine ethical and regulatory considerations in the development and use of biomedical technologies</td><td rowspan="4">LO3 and LO4

D3 Critically analyse any two emerging applications of biomedical engineering innovations with applications to practical settings, identifying relevant ethical and regulatory frameworks for the development of these innovations and their use.</td></tr>
<tr><td>P6 Examine the importance of ethical and regulatory frameworks in biomedical engineering.

P7 Summarise relevant regulations and frameworks for use and development of biomedical technologies and for research and clinical practice.</td><td>M4 Analyse the risks associated with application of biomedical technologies in research and practice.</td></tr>
<tr><td colspan="2">LO4 Discuss emerging trends and the outlook for biomedical engineering</td></tr>
<tr><td>P8 Discuss emerging trends in biomedical engineering and how they may be used in relevant settings, including social and stakeholder impact.</td><td>M5 Compare the use of any two emerging technologies and their potential to be applied in relevant healthcare/clinical or research settings.</td></tr>
</table>

Recommended Resources

Print Resources

Bainbridge, A.F. (2023) *Ethics for Engineers: A Brief Introduction.* Abingdon: CRC Press.

Banerjee, A., Chakraborty, C., Kumar, A. and Biswas, D. (2020) 'Emerging trends in IoT and big data analytics for biomedical and health care technologies'. In *Handbook of Data Science Approaches for Biomedical Engineering*, pp. 121–152. London: Academic Press.

Blinowska, K.J. and Żygierewicz, J. (2022) *Practical Biomedical Signal Analysis Using MATLAB®.* 2nd Ed. London: CRC Press.

Bronzino, J.D. and Peterson, D.R. (2018) 'Biomedical Engineering Fundamentals'. In *The Biomedical Engineering Handbook*, Volume 1. 4th Ed. Boca Raton, Florida: CRC Press.

Bronzino, J.D. and Peterson, D.R. (2017) *Biomedical Signals, Imaging, and Informatics.* In *The Biomedical Engineering Handbook*, Volume 3. 4th Ed. Boca Raton, Florida: CRC Press.

Douglas, Y. and Grant, M.B (2018) *The Biomedical Writer: What You Need to Succeed in Academic Medicine.* Cambridge: Cambridge University Press.

Enderle, J.D. and Bronzino, J.D. (2012) *Introduction to Biomedical Engineering.* 3rd Ed. London: Academic Press.

Essick, J. (2018) *Hands-On Introduction to LabVIEW for Scientists and Engineers.* 4th Ed. Oxford: Oxford University Press.

King, A.P. and Eckersley, R. (2019) *Statistics for Biomedical Engineers and Scientists: How to Visualize and Analyze Data.* London: Academic Press.

Kirk, A. (2019) *Data Visualisation: A Handbook for Data Driven Design.* 2nd Ed. London: SAGE Publications.

Levin-Epstein, M. (2019) *Careers in Biomedical Engineering.* London: Academic Press.

Miyauchi, A. and Miyahara, Y. (2022) *Biomedical Engineering.* Singapore: Jenny Stanford Publishing.

Narayan, R. (2018) *Encyclopaedia of Biomedical Engineering.* London: Elsevier.

Street, L.J. (2023) *Introduction to Biomedical Engineering Technology: Health Technology Management.* 4th Ed. Boca Raton, Florida: CRC Press.

Tranquillo, J., Goldberg, J. and Allen, R. (2022) *Biomedical Engineering Design.* London: Academic Press.

Websites

www.delsys.com	Delsys (General reference)
www.khanacademy.org	Khan Academy 'Descriptive statistics' (Training)
www.visualisingdata.com	Visualising Data (General reference)

Journals

Biocybernetics and Biomedical Engineering

Biomedical Engineering Advances

Biomedical Engineering Letters

Biomedical Signal Processing and Control

Current Opinion in Biomedical Engineering

Indicative equipment and other resources

Essential laboratory components (resistors, conductors, soldering board)

Oscilloscope

Power supply

Multimeter

Data acquisition system and software (e.g. LabVIEW)

Electromyography (EMG) sensors

Accelerometers/gyroscopes

An ultrasound system (optional)

Signal and image processing packages (e.g. MATLAB)

Note: This is not an exhaustive list and should only be used as a general guide in planning for suitable resources. Examples indicate the varied scope of facilities other institutions offer to aid delivery of the subject.

Links

This unit links to the following related units:

Unit 5057: Medical Instrumentation

Unit 4033: Programmable Logic Controllers

Unit Code: T/651/0760

Level: 4

Credits: 15

Introduction

The programmable logic controller (PLC) has revolutionised the automation industry. Since Richard Morley's Modicon invention at General Motors in the 1970s, the PLC has been the standard solution for industrial automation. Today PLCs can be found in everything from manufacturing equipment to vending machines, and PLC system development for automated systems is a highly specialised and demanding area of engineering.

The aim of this unit is to enable students to understand the rationale behind the use of programmable logic controllers and their applications in industry. The unit combines practical skills and knowledge in developing PLC applications from real scenarios with theoretical principles, such as communication and networking protocols.

On successful completion of this unit students will have developed an understanding of the evolution, types and applications of PLCs. They will know how to select and develop a PLC system, integrate features of functional safety based on their understanding of risk management, and evaluate the wide range of communication technologies available on modern PLCs.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the design, operation and selection of PLC systems

LO2 Explore Functional Safety within PLC systems

LO3 Develop a PLC program for an automated process system

LO4 Review how PLCs exchange information and process signals with other devices.

Essential Content

LO1 **Describe the design, operation and selection of PLC systems**

PLC architecture and operation:

central processing unit (CPU), data memory, program memory, speed, scan time, power supply, output current rating

Input/output (I/O) interface: digital, analogue, relay, transistors, TRIACs, opto-coupling.

PLC types and selection:

Compact, modular and rack-mounted

Distributed control systems and programmable automated controllers

PLC manufacturers

Latest PLC case studies.

LO2 **Explore Functional Safety within PLC systems**

Functional Safety standards:

Evolution of Safety and Risk management

IEC61508 (Electrical, Electronic and Programmable Equipment)

IEC61131 (PLCs), IEC61131-3 (Languages)

IEC61511 (Process Control) IEC62061 (Machinery)

Hazard and risk assessment

Hazard and operability analysis (HAZOP)

Failure modes and effects analysis (FMEA)

Fault tree analysis (FTA)

Safety integrity levels, redundancy (back-up or failsafe).

LO3 **Develop a PLC program for an automated process system**

Logic control circuits:

AND, OR, NAND, NOR, XOR, combinational logic, latching circuits.

Number systems:

Binary, decimal, hexadecimal, octal number representation and conversion

Memory: bits, bytes, nibbles, word, long/double

Signed and unsigned values.

PLC programming:

Industrial Standard IEC61131; PLC software tools

Ladder logic operation: rungs, input, process, output

Variables: Boolean, integer, floating point

Inputs, outputs, delay functions, timers, counters, latches, registers, comparison blocks, math operators, function blocks, simulation, debugging, hardware testing, fault finding

Peer review of programming activities (e.g., design, code, test plan), program demonstration and profession discussion including good practice.

Documentation:

Requirements and specification, flow chart, functional chart, sequence table, input/output or allocation list, wiring diagram, test data.

LO4 **Review how PLCs exchange information and process signals with other devices**

Digital communication basics:

Digital versus analogue communication: analogue to digital conversion (ADC), digital to analogue conversion (DAC)

Sampling rate, resolution, errors

Noise: decoding, encoding, pulse code modulation (PCM)

Elements of a digital communication system; digital communication medium.

PLC communication and networking:

Fieldbus, profibus, modbus, ethernet, profinet

OSI model, RS232, RS485, USB, parallel, serial

Controlled area network (CAN)

Supervisory control and data acquisition (SCADA)

Remote terminal unit (RTU)

Human–machine interface (HMI).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the design, operation and selection of PLC systems		
P1 Describe the architecture and operation of programmable logic controllers. **P2** Compare the design and applications of Compact, modular and rack-mounted PLCs. **P3** Describe the range of input/output devices and PLC interface techniques.	**M1** Analyse the suitability of programmable logic controllers (PLCs) with programmable automation controllers (PACs) for given applications.	**D1** Justify the selection of a programmable logic controller for a given application.
LO2 Explore Functional Safety within PLC systems		
P4 Explore the requirement of functional safety within industrial PLC systems. **P5** Compare the range of IEC6113-3 languages and their applications.	**M2** Apply functional safety analysis on a PLC based automated process system.	**D2** Evaluate functional safety and its integration into PLC systems to minimise hazards and risks.

Pass	Merit	Distinction
LO3 Develop a PLC program for an automated process system		
P6 Translate a digital logic control circuit into an equivalent PLC program. **P7** Produce design and planning documentation associated with the preparation of a PLC program. **P8** Design and develop a functionally safe PLC program for an automated process system.	**M3** Apply methods of testing and debugging hardware and software in PLC systems.	**D3** Evaluate the PLC program for an automated process system and make justifiable modifications.
LO4 Review how PLCs exchange information and process signals with other devices.		
P9 Describe the characteristics and methods of digital data communication for PLCs. **P10** Review common communication technologies available on a range of PLCs.	**M4** Assess the use and integration of SCADA and HMI's with PLCs in industry.	**D4** Evaluate fieldbus and Ethernet technologies for industrial manufacturing applications.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bolton W. (2015) *Programmable Logic Controllers*. 6th Ed. Elsevier.

Dawkins N. (ed.) (2014) *Automation and Controls: A guide to Automation, Controls, PLCs and PLC Programming*.

Johnson Jr C.H. and Sanusi A.L. (2022) *PLC Programming from Novice to Professional: Learn PLC Programming with Training Videos (Paperback).* Ojula Technology Innovations.

Manesis S. and Nikolakopoulos G. (2018) *Introduction to Industrial Automation.* 1st Ed. Routledge, Taylor and Francis Group.

Perez A. E. (2012) *Introduction to PLCs: A beginner's guide to Programmable Logic Controllers*.

Petruzella F. (2023) *Programmable Logic Controllers.* 6th Ed. McGraw Hill.

Stewart G.R. (2021) *Siemens Plc Programming For Beginners: [Step-by-Step Instructions] How Can I Quickly and Easily Learn PLC Programming at Home?* Independent publication.

White M.T. (2023) *Mastering PLC Programming: The software engineering survival guide to automation programming (Paperback)*. Packt Publishing Limited.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Automation and Remote Control

Automation

Electrical, Electronics and Communications Engineering (Applied Sciences)

IFAC Journal of Systems and Control

IEEE Journal on Robotics and Automation

IEEE Potentials (Programmable Logic Controllers)

International Journal of Automation and Control (IJAAC)

International Journal of Innovative Research in Technology & Science

Journal of AI, Robotics and Workplace Automation

Journal of Automation and Intelligence

Programmable Logic Controllers (Special issue)

Links

This unit links to the following related units:

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 4016: Instrumentation and Control Systems

Unit 4030: Industry 4.0

Unit 4068: Industrial Robots

Unit 5009: Further Programmable Logic Controllers (PLCs)

Unit 5021: Further Control Systems Engineering.

Unit 4034: Computer Aided Design (CAD) for Engineering

Unit Code: A/651/0762

Level: 4

Credits: 15

Introduction

Computer Aided Design (CAD) is the use of computer technology in engineering industries, enabling the exploration of design ideas, the visualising of concepts and to simulate how a design will look and perform in the real world prior to production. The ability to analyse, modify and optimise a Computer-Generated Image (CGI), object and/or 3D environment is an integral part of the design process in all areas of engineering.

This unit aims to provide students with opportunities to develop their understanding and knowledge of CAD software applications used in contemporary engineering, and the practical skills to utilise the technology within their own creative work.

On successful completion of this unit students will be able to learn about the current and prospective uses of CAD technology within engineering, and be able to produce CAD drawing, objects, 3D environments visualisations and understand the importance of document/revision control and Product Data Management (PDM) systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Defend the role of CAD in different engineering contexts and its influence on design and manufacturing processes in areas of specialist practice

LO2 Use 3D and 2D CAD software to produce models, assemblies, schemes, technical drawings and visualisations and technical drawings

LO3 Develop models, schemes, drawings and renderings, for a given project, using CAD software.

LO4 Evaluate the way in which CAD software may integrate into production processes.

Essential Content

LO1 **Defend the role of CAD in different engineering contexts and its influence on design and manufacturing processes in areas of specialist practice**

CAD environment:

CAD software applications

Products produced using CAD

Computer data storage of CAD files

CAD as used in Product design

Computer Aided Manufacturing (CAM)

Computer Aided Engineering (CAE)

CAD for Additive Manufacture (AM) technologies

Sustainability

CAD and Digital Twins

Latest CAD applications in wider Industry 4.0 setting.

Simulations.

LO2 **Use 3D and 2D CAD software to produce models, assemblies, schemes, technical drawings and visualisations**

2D Conventions:

Orthogonal Drawings

Isometric/Axonometric Drawings

Technical Drawing Scale

Line thickness/line types

Annotation

Issue Level (Revision Control)

Product Data Management (PDM).

3D Modelling Conventions:

Solid modelling

Surface modelling

Materials/surface finishes

Lighting.

Simulations:

Virtual simulations of systems and mechanisms

Advancements in CAD (e.g., Kinematics)

Animations

Renders

Finite Element Analysis (FEA)

Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (XR).

LO3 **Develop models, schemes, drawings and renderings, for a given project, using CAD software**

Drawing formatting:

Drawing sizes/sheet sizes

Visual representation

Accurate scaling

Dimensioning

Tolerancing Title blocks

Notes

Bill of materials (BOM)

Issue Level (Revision Control)

Product Data Management (PDM).

Output formats:

File types

Printing methods

Rendering methods

Wireframe

Hidden line

Shaded

Photorealistic.

Simulations

Rapid prototypes/physical models

Animations

Finite Element Analysis (FEA)

Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (XR).

LO4 **Evaluate the way in which CAD software may integrate into production processes**

Digital and non-digital workflows:

Integrating with other software.

Digital Production:

Bill of Materials (BOM)

Plant layout

Digital Prototyping.

Simulation & Analysis

Digital Twinning Product, component fitment or production facility

BIM Information

Visual animation for assembly/training

Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (XR).

Production:

Product Life cycle Management

Plant layout

Product Document Management

Assembly aids

Special Tools and Test Equipment (STTE)

Quality Assurance

Human Factors

Lifetime Records

Use of Cloud-based systems for storage and collaboration.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Defend the role of CAD in different engineering contexts and its influence on design and manufacturing processes in areas of specialist practice		
P1 Defend the use of Computer Aided Design (CAD) in different Engineering contexts. **P2** Explore CAD-enabled processes supporting Engineering activities.	**M1** Evaluate how the use of CAD may be beneficial, or problematic, in different Engineering contexts.	**D1** Assess the use of CAD to support manufacturing activities within an Industry 4.0 environment.
LO2 Use 3D and 2D CAD software to produce models, assemblies, schemes, technical drawings and visualisations		
P3 Use 2D drawings to explore the technical and physical parameters of an Engineering project. **P4** Develop 3D models and visualisations to experiment with form, material, and surface finish.	**M2** Use 2D and 3D CAD drawings and visualisations as part of an iterative Engineering development process.	**D2** Produce finished 2D and 3D CAD outputs, accurately scaled and conveying key technical information, dimensions, materials and surface finishes.

Pass	Merit	Distinction
LO3 Develop models, schemes, drawings and renderings, for a given project, using CAD software		**LO3 and LO4**
P5 Prepare a set of CAD drawings for a given project. **P6** Evaluate the ability of CAD to enhance a project workflow.	**M3** Use industry standard conventions in the production and presentation of 2D and 3D CAD output.	**D3** Present finished 2D and 3D CAD outputs to a technical audience, integrating the use of related software and traditional production techniques to develop outputs that communicate the technical and aesthetic properties of an engineering project.
LO4 Evaluate the way in which CAD software may integrate into production processes.		
P7 Evaluate the integration of CAD/CAM into own design and development process. **P8** Discuss how CAD may impact upon the design process.	**M4** Compare traditional and CAD enabled production in relation to efficiency and accuracy.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bethune J.D. (2019) *Engineering Design Graphics with Autodesk Inventor 2020*. 1st Ed. Pearson.

Bi Z. and Wang X. (2020) *Computer Aided Design and Manufacturing*. Wiley.

BS 8888 (2017) Technical product documentation and specification.

Metwalli S.M. (2021) *Machine Design with CAD and Optimization*. Wiley.

Omura G. and Benton B.C. (2014) *Mastering AutoCAD 2015 and AutoCAD LT 2015 Essentials*. Autodesk Official Press

Pitroda H. P (2019) *Computer Aided Design: Textbook and Practice book*. Walnut publication

Sarkar J. (2014). *Computer aided design: a conceptual approach*. CRC Press.

Shih R.H. (2024) *Principles and Practice: An Integrated Approach to Engineering Graphics and AutoCAD 2024*. 1st Ed. SDC Publications.

Shih R. (2022) *Learning SOLIDWORKS 2022.* SDC Publications.

Simmons C.H., Dennis E. and Maguire N.P. (2020) *Manual of Engineering Drawing – British and International Standards.* 5th Ed. Butterworth-Heinemann.

Stark J. (2021) *What Every Engineer Should Know about Practical CAD/CAM Applications*. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

CAD Journal – CAD and Applications

Computer-Aided Design

Computer-Aided Design and Applications

International journal of Computer Integrated manufacturing

International Journal of CAD/CAM

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4023: Computer Aided Design and Manufacture (CAD/CAM)

Unit 4027: CAD for Maintenance Engineers

Unit 5004: Virtual Engineering

Unit 5007: Commercial Programming Software.

Unit 4035: Welding Technology

Unit Code: D/651/0763

Level: 4

Credits: 15

Introduction

Many of the things we take for granted, such as motor vehicles, buildings and bridges, rely on welded joints to hold them together. The in-service performance of a welded joint depends on many factors including the selected welding process, the materials being joined, the skill of the operator and the subsequent service conditions of the welded joint and the host component.

This unit introduces students to a range of manual and automated welding processes, equipment and applications that form part of the manufacturing process of joining by welding. The importance of the underpinning metallurgical properties of the weld materials, the effect of heat and weld induced stress and the importance of correct weld design and implementation will also be covered.

On the successful completion of this unit the student will be able to describe common welding processes and demonstrate how the metallurgical properties of the weld materials, the correct weld design and implementation affect the performance of the weld during and post, welding operations.

Note: Welding and welding inspection are primarily practical tasks. This unit, together with Unit 4036: Welding Inspection, has been designed to support practical training in welding and welding inspection with the appropriate and necessary theory. It is anticipated that a student studying this unit will have prior experience of welding at Level 3.

Learning Outcomes

LO1 Describe the fundamental principles of welding processes and equipment

LO2 Demonstrate how the metallurgical properties of weld materials effect the performance of welded joints

LO3 Show how weld construction and design can influence the behaviour of welded structures under different types of loading

LO4 Demonstrate how weld stresses can affect a weld construction, their causes, avoidance and control measures.

Essential Content

LO1 Describe the fundamental principles of welding processes and equipment

Oxy-gas welding and related processes:

Fundamentals of oxy-gas combustion

Characteristics of different fuel gases.

Fundamentals of an electric arc:

Characteristics; limitations and applications

Power sources for arc welding, difference performance of AC/DC sources, importance of polarity

Shielded arc welding; purpose of gas shield, types of gas used, control of shield gas and post weld operations. Effect of shielding gas on the post-weld properties of the weld joint.

Fundamentals; equipment, applications and procedures for welding processes:

Tungsten-inert gas (TIG) welding

Metal Inert Gas (MIG)/Metal Active Gas (MAG) and Flux Cored welding

Manual Metal arc welding

Submerged-arc welding

Resistance welding.

Other welding and associated processes:

Plasma, electron beam, Laser, electro-slag, friction, magnetic pulse welding, ultrasonic, high-frequency, stud and others

Cutting and other edge preparation processes

Automated/fully mechanised processes and robotics.

LO2 Demonstrate how the metallurgical properties of weld materials effect the performance of welded joints

Requirements for testing materials and welded joints:

Quality control, regulations governing welded structures, UK, European and International. Methods of examination of welding joints, applications and differences between macro and micro-structural composition and examination.

Structure of the welded joint:

Formation and properties of the different metallurgical structures within a weld, variation with process, temperature and material. Definition and importance of the Heat Affected Zone (HAZ). Need for multi-pass joints and possible problems compared to single pass welded joints.

Metallurgical effects induced by welding in:

Carbon and Carbon-Manganese steels.

High-alloyed (stainless) steels

Cast irons and cast steels

Nickel and Nickel alloys

Aluminium and aluminium alloys.

Cracking mechanisms in welded joints:

Short and long-term effects, causes and avoidance measures, monitoring to prevent poor welds.

Principles of joining dissimilar materials:

Requirement for welding dissimilar materials, precautions and safeguards, processes and testing.

LO3 **Show how weld construction and design can influence the behaviour of welded structures under different types of loading**

Influences affecting welded joint design:

Material being welded, plate or sheet thickness, wall thickness of welded pipes, accessibility, loading, welding process, rate of heat input and total heat input, welding position.

Relationship between external loads on structures, internal forces and the stresses induced by welds:

Strength of welded joint and weld area, loads across discontinuous surfaces, surface finish. Effect of in-service, post-weld, operational temperatures and pressures (internal and external).

Behaviour of welded structures under dynamic and static loading:

Design of welded pressure equipment for different applications (corrosive content, medical, aerospace and nuclear). Design of aluminium alloy structures under varying loads and in differing environments. Use of protective coatings.

LO4 **Demonstrate how weld stresses can affect a weld construction, their causes, avoidance and control measures.**

Contraction and distortion due to weld induced stress in joints and structures:

Control Measure and procedures to minimise distortion and stress, effects of induced stresses on the behaviour of a structure in service. Causes and relief of post-weld residual stresses. Consideration of all process variables, previously described on LO2 on weld induced stress, including: Formation and properties of the different metallurgical structures within a weld, variation with process, temperature and material. Importance of the Heat Affected Zone (HAZ). Problems caused by use of multi-pass joints.

Plant facilities, welding jigs and fixtures:

Workshop layout for improved productivity, safety and comfort

Advantages of using fixtures, jigs and positioners, auxiliary equipment, fume extraction, heat treatment and temperature control equipment

Facilities for handling and storing welding consumables.

Health and safety hazards associated with welding and fabrication processes:

Risk factors associated with welding from electricity, gases, fumes, fire, radiation and noise.

Health and safety regulations:

National, European and international regulations and codes of practice. Safe working procedures to ensure the requirements are met, operator skills updating and testing.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the fundamental principles of the welding processes and equipment		
P1 Describe the fundamental characteristics of the electric arc and oxy-gas welding. **P2** Explain how the selection of current (AC/DC) and polarity can affect the structure of the weld.	**M1** Explain how the choice of shielding gas can affect the properties of a weld.	**D1** Evaluate the most appropriate welding process for a given application and material type.
LO2 Explain how the metallurgical properties of weld materials effect the performance of welded joints		
P3 Illustrate how the areas of the Heat Affected Zone (HAZ), and their influence on the material properties of the weld. **P4** Describe the process of the specimen preparation for micro and macro examination.	**M2** Explain how multi-pass welds can significantly reduce stress in the weld microstructure.	**D2** Discuss the fundamentals of cracking mechanisms in welded joints and the way in which welding variables affect the incidence of cracking.
LO3 Show how weld construction and design can influence the behaviour of welded structures under different types of loading		
P5 Show how weld construction and design can influence the behaviour of welded structures under different types of loading.	**M3** Explain the effect that high pressure and temperature can have on a weld construction over time.	**D3** Analyse the importance of welding joint design and how it can be influenced by material type, material thickness, accessibility, loading, welding process and welding position.
LO4 Explore how weld stresses can affect a weld construction, their causes, avoidance and control measures.		
P6 Explore how welding sequence and techniques can help to reduce residual stresses or distortion. **P7** Investigate the advantages of using fixtures, jigs and positioners.	**M4** Demonstrate how residual stresses may affect the behaviour of a structure in service.	**D4** Assess how health and safety regulations relating to the welding process are most effectively applied.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Currant H. (Editor) (2023) *Welding: Advanced Principles and Applications* (Hardback). Larsen and Keller Education.

Messler R. W. (2015) *Principles of Welding: Processes, Physics, Chemistry, and Metallurgy*. Wiley.

Sinclair C. (2023) *Welding for Beginners in Fabrication: The Must-Read Complete Guide* (Paperback). Caleb Sinclair

Sind K. (2021) *Welding Metallurgy*. 3rd Ed. Wiley.

Timings, R (2017) *Fabrication and Welding Engineering*. Taylor & Francis Ltd

Websites

www.theweldinginstitute.com	The Welding Institute is the leading international membership body for welding and joining professionals. (General reference)
www.iiwelding.org	International Institute of Welding operates as the global body for the science and application of joining technology, providing a forum for networking and knowledge exchange among scientists, researchers and industry. (General reference)

Links

This unit links to the following related units:

Unit 4003: Engineering Science

Unit 4007: Machining and Processing of Engineering Materials

Unit 4009: Materials, Properties and Testing

Unit 4014: Production Engineering for Manufacture

Unit 4036: Welding Inspection

Unit 4068: Industrial Robots.

Unit 4036: Welding Inspection

Unit Code: **M/651/0895**

Level: **4**

Credits: **15**

Introduction

Welding is a widely used, safe and reliable method of joining materials. The strength and integrity of the welded joint is fundamental to its in-service performance. This performance is assured by vigorous inspection processes which form part of a comprehensive quality control programme.

This unit introduces students to the role of inspection in weld construction, the purpose and value of welding procedure and welder performance testing, as well as the range of non-destructive testing methods that can be employed to identify weld imperfections that could lead to in-service failure. The role and operation of quality assurance systems is also covered.

On the successful completion of this unit the student will be able to describe the purpose of weld process and operator performance testing, demonstrate an understanding of a range of non-destructive methods, their application and limitations. They will appreciate the roll and operation of quality assurance systems and be able to identify the most appropriate testing method with regard to material type, size and potential weld imperfections as well as an understanding of the economic impact resulting from failure of the joints for people, products and the environment.

Note: Welding and Welding Inspection are primarily practical tasks, this unit, together with Unit 4035: Welding Technology have been designed to support practical training in welding and welding inspection with the appropriate and necessary theory. It is anticipated that a student studying this unit will have prior experience of welding at Level 3.

Learning Outcomes

LO1 Describe the role and importance of inspection in weld construction

LO2 Illustrate the purpose and value of welding procedure and welder performance testing

LO3 Explain the operation and application of Non-destructive Testing (NDT)

LO4 Demonstrate the role of quality assurance systems in the welding process.

Essential Content

LO1 Describe the role and importance of inspection in weld construction

Requirements for testing materials and welded joints:

Quality control, regulations governing welded structures, UK, European and International. Special application testing, e.g. nuclear

Need for inspection of the weld process and operator inspection

Roles and responsibilities of welding inspectors, relationship with other welding and inspection personnel. Role in maintaining standards of production and post-weld performance.

Testing methods:

Overview of purpose and operation of destructive and non-destructive testing

Types of destructive testing used in weld process and operator inspection.

Terminology:

Terms and definitions used in testing and inspection processes.

LO2 Illustrate the purpose and value of welding procedure and welder performance testing

Testing requirements:

Test requirements for procedure and performance testing/standardisation.

Weld imperfections:

Clarify the characteristics of the fundamental types, possible position of weld imperfections and defects, their visibility with the current non-destructive testing (NDT) techniques

Morphology of weld imperfections and their possible influence. National, European and international standards and codes for acceptance/rejections of weld imperfections.

Types of destructive testing used in weld process and operator inspection:

Sectioning of weld joint, preparation for inspection, etching and examination. Macro etch testing, fillet weld break test, transverse tension test and guided bend test.

LO3 **Explain the operation and application of Non-destructive Testing (NDT)**

Fundamentals, applications and specifications of NDT:

Operating principles and applications of: Liquid penetrant testing (LPT), magnetic particle testing (MPI), radiographic testing (RT), ultrasonic testing (UT) and Eddy current testing (ECT). Computed tomography (CT) scanning and developed acoustic emission techniques.

Interpretation and economics of testing:

Interpretation of specific imperfections in welds revealed by above tests. Economic considerations of testing operations applied to welded fabrications.

LO4 **Demonstrate the role of quality assurance systems in the welding process.**

Quality assurance:

Principles and levels of quality assurance, systems and operational consideration. Importance of accurate record keeping and monitoring of activities

Quality assurance responsibilities associated with inspection activities as they relate to individuals, company organisation, generation and retention of records

Risks related with a collapse or a failure of the joints for individuals, organisation, products and environment.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the role and importance of inspection in weld construction		**D1** Evaluate the role of inspection in assuring product quality.
P1 Describe the role and responsibilities of welding inspectors. **P2** Explain welding inspection and NDT terms.	**M1** Analyse the purpose and value of testing in relation to service performance.	
LO2 Illustrate the purpose and value of welding procedure and welder performance testing		**D2** Evaluate how defects can impact on in-service performance of components and structures.
P3 Illustrate the different type of commonly encountered weld imperfections. **P4** Specify the most likely causes of weld imperfections to the different welding processes and welded materials.	**M2** Explain the requirements for materials used for procedure and performance testing/ standardisation.	

Pass	Merit	Distinction
LO3 Explain the operation and application of Non-destructive Testing (NDT)		
P5 Identify the types and location of imperfections expected to be found using magnetic particle and dye penetrant testing techniques. **P6** Describe the principles of ultrasonic, radiographic and Eddy Current testing techniques.	**M3** Explain how accuracy of detection is related to NDT processes, material type and size of construction.	**D3** Evaluate NDT methods in terms of the interpretation and economics of testing operations.
LO4 Explore how weld stresses can affect a weld construction, their causes, avoidance and control measures.		
P7 Describe the role of the inspector during fabrication activities. **P8** Illustrate the importance of keeping accurate records and monitoring of activities with respect to the inspection process.	**M4** Analyse the responsibilities associated with inspection activities as they relate to individuals, company organisation, generation and retention of records. **M5** Differentiate between the inspection process and the role of a quality assurance process.	**D4** Evaluate the risks related to a collapse or failure of welded joints for individuals, organisations, products and the environment.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Hughes S. E. (2009) *A Quick Guide to Welding and Weld Inspection*. Elsevier.

Singh R.P. (2020) *Applied welding engineering processes, codes, and standards*. 3rd Ed. Elsevier.

Wong, S.B. (2014) *Non-Destructive Testing – Theory, Practice and Industrial Applications*. Saarbrücken: LAP (Lambert Academic Publishing)

Websites

www.theweldinginstitute.com	The Welding Institute is the leading international membership body for welding and joining professionals. (General reference)
www.bindt.org	British Institute of Non-Destructive Testing. Covering NDT in its widest sense. Each issue includes technical articles on a broad range of subjects and general news stories affecting the whole industry. (General reference)

Links

This unit links to the following related units:

Unit 4003: Engineering Science

Unit 4007: Machining and Processing of Engineering Materials

Unit 4009: Materials, Properties and Testing

Unit 4014: Production Engineering for Manufacture

Unit 4035: Welding Technology

Unit 4037: Statistical Process Control

Unit 4068: Industrial Robots.

Unit 4037: Statistical Process Control

Unit Code: F/651/0764

Level: 4

Credits: 15

Introduction

Control charts and measurements are methods used to detect trends and quality variations in the output of processes, allowing early warnings of deviations from specifications. These signals are then used to initiate corrective actions in production planning, process method, modification and maintenance of systems. SPC forms an important part of most process improvement methodologies, such as Total Quality Management and Six Sigma.

This unit introduces the student to the statistical techniques used in process control, variables inspection and attributes inspection. The collection and handling of data and its interpretation using process control charts is covered. These skills will allow the student to assess process capability and recognise types of variability that may occur in different processes.

By the end of this unit, students will be able to apply relevant statistical techniques used in process quality control and to evaluate the outcome of a process against the desired specification.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Review the quality control function of inspection and measurement

LO2 Select data to construct process control charts and determine a control program for a specified application

LO3 Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits

LO4 Report the variation found within the output of a process.

Essential Content

LO1 Review the quality control function of inspection and measurement

Importance of quality control in all organisations:

Use of basic techniques to meet the objectives of quality control
Evaluation of basic types, variables inspection, precision measurements of physical characteristic, e.g. weight, surface finish etc.
Attribute inspection: Pass/Fail, Go/NoGo, Accept/Reject.

Variability:

All processes are subject to some degree of natural and assignable variability which may change due to process methods used and cumulative effects such as wear and tear on individual components.

Mathematical methods:

Used to quantify variations and characteristics: frequency, mean, standard deviation (SD)

Control limits/allowable tolerances within specified standard deviation values considered.

Accuracy:

Function of the accuracy of the process; relate to the design specification requirement

Errors in tool setting, wear and tear, material variation and skill of operator/programming.

LO2 **Select data to construct process control charts and determine a control program for a specified application**

Sample data:

Physical variables and attributes such as weight, length, diameter

Defects per unit area/length.

Data grouping:

Data grouped in tabular form, sample means

Bulk means and SD values calculated using appropriate software

Process and control charts created

Upper and lower control limits decided, based on appropriate standards to meet design specification conditions.

LO3 **Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits**

Modified control charts:

Allowing flexibility to respond to long-term variations, whilst maintaining control within specified tolerances.

Limits:

Distinction between specification limits and control chart limits

Reduction of variability and the effects on precision in terms of SD for a particular component or product

The relative precision index of a process and hence its capability and capacity.

LO4 **Report the variation found within the output of a process.**

Types of variation:

Process used

Common effects

Special effect.

Recording variation:

Charts – linear recording, time versus output, histograms, Pareto diagrams, stem and leaf plots

Computer data acquisition systems and visual display benefits.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Review the quality control function of inspection and measurement		
P1 Review the importance of inspection and measurement in the quality control of a process. **P2** Distinguish the significance between natural and assignable causes of variation.	**M1** Analyse data to construct the frequency distribution and calculate the mean, range and standard deviation of a given process.	**D1** Evaluate how the monitoring of process outputs can be used to ensure standards and conformance to a given design specification are maintained.
LO2 Select data to construct process control charts and determine a control program for a specified application		
P3 Explain how data can be chosen to create process control charts that will enable decisions to be made effectively. **P4** Select data to construct process control charts and present.	**M2** Analyse sample data from variable inspection and attributive inspection to determine appropriate control chart limits.	**D2** Initiate a control program for a specified application.
LO3 Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits		
P5 Describe the characteristics that need to be considered when determining the process capability of a given process.	**M3** Analyse the purpose of modified control chart limits.	**D3** Evaluate the processes of a system against a given quality requirement.
LO4 Report the variation found within the output of a process**.**		
P6 Demonstrate effective and accurate methods to record variation in output quality of a range of processes.	**M4** Analyse variations of a process output and deduce cause and effect on finished artefact or service.	**D4** Determine an effective response to any deviation from the acceptable quality thresholds.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Amsden, R.T. and D.M. (1998) *SPC Simplified: Practical Steps to Quality*. New York: Productivity Press.

Montgomery D. C. (2019) *Introduction to Statistical Quality Control*. 8th Ed. Wiley.

Oakland J. S. (2019) *Statistical process control.* Routledge Taylor & Francis.

Wheeler, D.J. (2010) *Understanding SPC*. 3rd ed. Knoxville, Tennessee: SPC Press.

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4017: Quality and Process Improvement

Unit 4074: Workplace Study and Ergonomics

Unit 4075: Business Improvement Techniques for Engineers

Unit 4077: Lean Techniques for Manufacturing Operations.

Unit 4038: Telecommunication Principles

Unit Code: **H/651/0765**

Level: **4**

Credits: **30**

Introduction

Telecommunication deals with the transmission of information such as voice, images and data using three elements: transmitter, medium and receiver. Applications of telecommunications are all around us including mobile phones, satellite TV, computer networks, Bluetooth and Wi-Fi.

This unit starts with the fundamental principles of wireless communication systems including frequency spectrum and the sources of noise and interference. Theories and practices of analogue and digital communication are then analysed. The unit further covers the physical practicalities of telecommunication systems such as guided and unguided transmission media, security and network architectures.

It is essential that students have successfully completed level 4 or equivalent units containing electrical circuit theory and analogue/digital electronics before undertaking this unit.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Develop fundamental knowledge of analogue electronic communication

LO2 Analyse digital communication techniques

LO3 Assess transmission channels and applications

LO4 Investigate the design of Data Networks.

Essential Content

LO1 **Develop fundamental knowledge of analogue electronic communication**

Characteristics and performance:

Sinusoid relationships: frequency, wavelength and velocity

RF spectrum: ULF, LF, MF, VHF and EHF, Bandwidth, Gain and Attenuation, use of the decibel (dB) Noise: Sources; Internal, external, natural and man-made. Effects; Interference, cascaded systems, Calculations; signal to noise ratio, thermal noise, noise factor and power.

Modulation Techniques:

Amplitude modulation (AM); Applications, carrier frequency, baseband signal, mixers, time and phase representation, modulator and de-modulator circuits, double sideband suppressed carrier (DSB-SC), single sideband suppressed carrier (SSB-SC). Frequency modulation (FM); Applications, Bessel coefficients, Carson's rule, wideband, narrowband, varicap diode circuit, crystal-controlled phase locked loop (PLL), PLL demodulator circuits. Phase Modulation (PM); Phase shift keying; Binary, Quadrature, 8 point and 16 point.

RF Transmitter and Receiver Circuits:

Transmitters; Oscillators, Modulation, Power Amplifiers, Matching, Antennas. Receivers; Low Noise Amplifiers, Mixers, Tuning Circuits, Detectors. Filtering; Bandpass Chebyshev and Butterworth designs. The Super Heterodyne Receiver.

LO2 **Analyse digital communication techniques**

Digital Communication Fundamentals:

Digital Data; Coder-Decoder (CODEC), Baud Rate, Bandwidth, Multiplexing

Analogue to Digital Conversion (ADC); Dynamic range, quantization error, conversion rate, noise. Sampling, Nyquist Theorem, Digital to Analogue Conversion (DAC); Accuracy, Linearity, Monotonicity, Conversion time, Resolution Shannon's Theory, Design trade-offs meeting objectives against constraints.

Digital Modulation:

Data transmission; Baseband digital signalling, digital receiver/generator, non-return to zero (NRZ) and return to zero (RZ), Spectrum of a pulse, effects of noise, raised cosine filter, limitations of baseband signalling. Pulse Coded Modulation (PCM); Carrier Based Signalling; Amplitude shift keying (ASK), Frequency shift keying (FSK), Phase shift keying (PSK), Binary phase shift keying (BPSK), filtering techniques, Digital Signal Processors (DSP)

Orthogonal frequency division multiplexing; Quadrature amplitude modulation (QAM) and Quadrature phase shift keying (PSK).

Coding and Decoding; Hamming, Cyclic-Redundancy, Convolution, Maximum-likelihood Viterbi, Reed-Solomon.

LO3 **Assess transmission channels and applications**

Characteristics and Selection criteria:

Transmission line theory; reflections, standing waves and return loss

Channel terminology; Propagation delay, attenuation, data transfer rate security, mechanical strength, physical dimensions, throughput. configuration, gauge, bandwidth, error performance, distance, cost, capacity.

Media Types:

Guided; Copper wires, twisted pair, coaxial cable, fibre optics, power line carrier

Unguided; Infrared, radio wave, microwaves, lasers, satellite radio.

Applications:

Telephone, computer data transfer, television, radio frequency transmitters and receivers, digital audio, satellite communication, Ethernet, smart grids, video, Bluetooth, paging, global positioning system (GPS), Wi-Fi, WiMax, Radar, Dedicated Short Range Communication (DSRC) for vehicles, internet of things.

Security:

Implications of unsecured wireless network

Classifications; spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege (STRIDE)

Standards; ISO27002, IEC-62443.

LO4 **Investigate the design of Data Networks.**

Network Types:

Personal Area Network (PAN), Local Area Network (LAN), Metropolitan Area Network (MAN), Wide Area Network (WAN), Internetwork (Internet).

Network Topologies:

Point-to-point, Bus, Star, Ring, Mesh, Tree, Daisy Chain, Hybrid.

Network Layers:

Open System Interconnect (OSI) standard layers; Application, Presentation, Session, Transport, Network, Data Link, Physical

Internet Model; TCP/IP protocol suite.

Network Security:

Threats; Interruption, Privacy-Breach, Integrity, Authenticity

Cryptography encryption; Secret Key, Public Key, Message Digest.

Network Switching:

Categories; Circuit, Message, Packet. Schemes; Space/time division.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Develop fundamental knowledge of analogue electronic communication systems		
P1 Identify the range of radio frequency (RF) bands and their applications. **P2** Examine types of noise, their sources and effects on electronic communication systems. **P3** Discuss the range of applications inductors and capacitors in play in RF transmitters and receivers. **P4** Differentiate modulation techniques by comparing Amplitude (AM), Frequency (FM) and Phase Modulation (PM).	**M1** Illustrate the sections of a complete RF transmitter and receiver system outlining the function of each section. **M2** Evaluate the properties of radio antennas and compare designs for AM and FM communication.	**D1** Design a theoretical bandpass filter circuit as part of an RF receiver from a given specification.
LO2 Analyse digital communication techniques		
P5 Explain the aliasing problem of sampled data and methods to mitigate this. **P6** Analyse the main performance specifications for ADC and DAC in a digital communication system. **P7** Describe the operation of a multiplexed PCM transmitter system. **P8** Compare different techniques to modulate and demodulate digital data.	**M3** Discuss a range of methods to reduce noise and improve the quality of signals in digital communication systems. **M4** Analyse coding methods for transmission reliability in digital communication.	**D2** Evaluate the trade-offs when meeting design objectives under the constraints and limitations of digital communication.

Pass	Merit	Distinction
LO3 Assess transmission channels and applications		
P9 Define the general characteristics of transmission channel media. **P10** Assess guided and unguided transmission channel media including applications.	**M5** Investigate security issues of unguided communication systems and methods of mitigating the risks.	**D3** Select and justify a guided or unguided communication system solution for a given case study.
LO4 Investigate the design of Data Networks.		
P11 Describe the geographical categories of data networks. **P12** Illustrate the differences between popular data network topologies. **P13** Explain with examples the principles of layered architecture for data networking. **P14** Investigate switching techniques in data networks.	**M6** Investigate methods to control traffic congestion on data networks.	**D4** Present a design proposal for a data network for a given specification.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Dodd, A.Z. (2018) *The essential guide to Telecommunication*, Prentice Hall.

Frenzel L. (2023*) Principles of Electronic Communication Systems*. 5th Ed. McGraw-Hill.

Horowitz, P. and Hill, W. (2015) *The Art of Electronics.*

Sibley, M. (2018) *Modern Telecommunications Basic Principles and Practice*s, CRC Press.

Young, P.H. (1998) *Electronic Communication Techniques,* Macmillan Publishing.

Website Tutorials

Store.tutorialspoint.com (2020) Premium Ebooks – Tutorialspoint [online] Available at: https://store.tutorialspoint.com/

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 5014: Analogue Electronic Systems.

Unit 4039: Semiconductor Manufacture

Unit Code: L/651/0768

Level: 4

Credits: 15

Introduction

Semiconductor device fabrication is a complex production process, involving varying technologies, concepts and specialist equipment and techniques. Each activity can be prone to defects, causing costs to rise and failure to meet customers specifications and reliability. The manufacture of semiconductor wafers and module packages is highly automated to ensure standards are met and yield is maximised.

This unit investigates the equipment and processes used in automated semiconductor device production and module assembly. The physical dimensions of the materials that are being processed are exceedingly small (<10nm) and so to prevent risk of contamination and defects the automatic production environment is hermetically sealed. The external working area is supplied with filtered air. In manufacturing semiconductor devices, it is important to be confident that the device will meet specifications, testing and data collection is both manual and automated, and the information used to confirm process quality and meet wafer yield predictions; any defects are identified and corrective actions taken.

The equipment and techniques used are specialised and it is important to become familiar with the technical language and concepts used to fully develop your skills.

On successful completion of this unit, students will be able to work effectively within the increasingly complex semiconductor manufacturing systems in the semiconductor industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the operational characteristics, selection criteria and application of equipment used in automated systems for fabricating semiconductor devices

LO2 Explain the individual process stages in producing a semiconductor wafer suitable for further processing in an automated semiconductor fabrication plant

LO3 Discuss the processes necessary to take a semiconductor wafer and produce a finished integrated circuit in an automated semiconductor fabrication plant

LO4 Demonstrate how the data collected during the semiconductor manufacturing process from inspection and testing is used to improve the yield of each integrated circuit to final packaging.

Essential Content

LO1 **Describe the operational characteristics, selection criteria and application of equipment used in automated systems for fabricating semiconductor devices**

Semiconductor device fabrication:

Overview of the entire semiconductor device fabrication manufacturing process

Introduction to terminology, e.g. wafers, deposition, removal, growth, patterning, modification, insulation, interconnectivity

Underlying principles of how the first semiconductors (Germanium (Ge) and Silicon (Si) material and Negative-Positive-Negative (NPN) and Positive-Negative-Positive (PNP) transistors) were produced. Characteristics of Bipolar junction devices

A systems approach to integration of semiconductor devices

Principles of Metal-Oxide-Semiconductor (MOS) technology, Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET).

Operational characteristics and selection of automated equipment for semiconductor fabrication:

System characteristics of generic semiconductor automated fabrication equipment, e.g., modular, unitary and rack mounted systems

electrical/mechanical/power characteristics, electronic parameters-speed, scan time, memory, Human Machine Interface, Input/output requirements, communication standards.

LO2 **Explain the individual process stages in producing a semiconductor wafer suitable for further processing in an automated semiconductor fabrication plant**

Producing a Pure Silicon wafer:

The need for a clean environment

Producing a silicon ingot, Czochhralski or Floating Zone process

Semiconductor purity

Preventing contamination.

Cutting the individual wafers:

Surface treatments, solvents, polished to obtain a very regular and flat surface

Thermal Oxidation

Testing of wafer-conductivity

Automatic handling and storage

Equipment needed to produce a semiconductor wafer, e.g., furnaces for oxidation and gas application, cutting tools to slice the silicon ingot into wafers, cleaning and surface treatment equipment, testing equipment for wafer flatness, surface conductivity, wafer automatic handling equipment.

LO3 **Discuss the processes necessary to take a semiconductor wafer and produce a finished integrated circuit in an automated semiconductor fabrication plant**

Wafer fabrication (Front-End):

Multi-step wafer fabrication process. i.e. photo-masking; etching; diffusion; ionic implantation; metal deposition; passivation and back-lap

Wafer-probing, i.e. process parametric test, full wafer probing test, bad die marked for removal after wafer is cut

Equipment needed to perform front-end wafer fabrication, e.g., diffusion furnaces, pumps to control flow of gasses, Ion implantation and vacuum equipment, Physical Vapour Deposition system, evaporation and sputtering chambers, Chemical Vapour Deposition equipment, photolithography equipment – resist coating – soft bake ovens – exposure equipment – development of resist to remove or retain mask pattern, wet and dry etching (Chemical or Plasma), waste removal equipment, automatic testing and sorting equipment, automatic handling equipment.

Wafer packaging and module assembly (Back-End):

Assembly, i.e. die cutting; inspection and sorting; die attachment to a frame or substrate; wire bonding (or alternative); further inspection and sorting; package encapsulation; leads cutting (if necessary); lead tinning (if necessary); marking; surface mount technology (SMT) and final test

Equipment needed to perform back end wafer fabrication, e.g. assembly process equipment includes – die cutting equipment and die attachment/bonding machines- automatic handling/holding- pick and place machines, wire bonding equipment and tools – die placement equipment, glass passivation equipment, moulding process equipment, high precision dispensers, deflash, trim, form and singulation machine (DTFS), solder paste printers, SMT component placer, flux wash system, laser marking and final automatic quality test equipment.

LO4 **Demonstrate how the data collected during the semiconductor manufacturing process from inspection and testing is used to improve the yield of each integrated circuit to final packaging.**

Data collection:

Automated data collection during manufacturing process

Automatic visual tests to identify defects caused by process activity

Critical Dimension Scanning Electron Microscope (CDSEM)

Go-No/Go Tests

Parametric test- dynamic checks.

Batch production testing issues.

Yield analysis:

Types of faults/defects recorded and analysed to improve future performance

Failure Mode and Effects Analysis (FMEA)

Process Failure Mode and Effects Analysis (PFMEA).Equipment needed to perform data collection and yield analysis, e.g. automatic test equipment, visual automatic inspection system, data acquisition equipment, software programmes to analyse the data and inform operators in real time. Yield management processes and control plans.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the operational characteristics, selection criteria and application of equipment used in automated systems for fabricating semiconductor devices		
P1 Describe the operational characteristics of the system for fabricating semiconductor devices on a wafer. **P2** Explain the difference in semiconductor structure between how a Bipolar junction transistor and MOSFET are made.	**M1** Explore the selection criteria and application of equipment used in semiconductor fabrication.	**D1** Analyse the system characteristics of an semiconductor fabrication facility.
LO2 Explain the individual process stages in producing a semiconductor wafer suitable for further processing in an automated semiconductor fabrication plant		
P3 Describe different methods of producing a silicon ingot.	**M2** Discuss the need for controlling the environment around the production of semiconductor wafers.	**D2** Evaluate the methods used to prepare a semiconductor wafer for wafer fabrication.
LO3 Discuss the processes necessary to take a semiconductor wafer and produce a finished integrated circuit in an automated semiconductor fabrication plant		
P4 Explain the various stages of Front-End and Back-End wafer fabrication.	**M3** Explore the methods used to connect the semiconductor chip to the printed wiring board.	**D3** Evaluate the methods of wafer testing used during the manufacturing process.
LO4 Demonstrate how the data collected during the semiconductor manufacturing process from inspection and testing is used to improve the yield of each integrated circuit to final packaging.		
P5 Describe how data is collected during the semiconductor manufacturing process. **P6** Investigate inspection and testing techniques used to improve semiconductor manufacturing processes.	**M4** Identify the principle types of faults and defects likely to occur in a semiconductor manufacturing processes.	**D4** Analyse how data from the manufacturing process is used to improve overall yield.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson B. and anderson R. (2018) *Fundamentals of Semiconductor Devices.* 2nd Ed. McGraw-Hill.

Balasinski A. (2012) *Integrated Circuit Design for Manufacturability*. CRC Press.

Evstigneev M. (2022) *Introduction to Semiconductor Physics and Devices*. Springer.

Geng H. (2017) *Semiconductor Manufacturing Handbook*. 2nd Ed. McGraw-Hill.

Hughes, E., Hiley, J., Brown, K. and McKenzie-Smith, I. (2012) *Electrical and Electronic Technology*. Pearson.

May G. and Spanos C. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. John Wiley & Sons, Inc.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

IEEE Transactions on Semiconductor Manufacturing

IET Digital Library

Transactions on Semiconductor Manufacturing

Links

This unit links to the following related units:

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 4040: Semiconductor Production Environments

Unit Code: Y/651/0770

Level: 4

Credits: 15

Introduction

As designers and engineers develop ever more sophisticated electronic equipment, the drive to package increasing amounts of processing power into smaller spaces is relentless. The size of semiconductor devices is measured in nanometres; one nanometre is one billionth of a metre in length and microchips of 10 nanometres are commonplace. Manufacturing devices of this size and complexity is a very specialist process and this unit addresses some of the important issues fundamental to safe and successful manufacture of semiconductors.

The production and assembly of semiconductor devices takes place in factory spaces that are closer in appearance and function to hospital operating theatres than conventional factories. A tiny speck of dust or grease can wreck production, this coupled with the toxic nature of some semiconductor manufacturing materials and processes, calls for particular attention to health, safety and working practices.

This unit will introduce the concept of cleanrooms, explore their design, internal layout and specialist equipment and furniture. The need to control air flow rates and levels of purity in cleanrooms will also be covered as will the need for, and proper use of, personal protective equipment (PPE). The certification, maintenance and cleaning of these facilities together with all aspects of the relevant Health & Safety legislation, good working practices and the concept of Good Manufacturing Practice (GMP) will be introduced. The nature of the toxicity present in semiconductor materials and manufacturing processes will be evaluated. Finally, the assessment and minimisation of risk will be considered.

On successful completion of this unit the student will be familiar with the nature of semiconductor manufacturing operations and be competent to work within such an environment, safely and in a knowledgeable manner, able to identify, assess and minimise risks to processes and people.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Recognise the role and applicability of Health and Safety legislation and other guidelines in semiconductor manufacturing

LO2 Describe the different cleanroom arrangements and their relevance to semiconductor manufacturing

LO3 Investigate the toxicity of the materials and processes employed in semiconductor manufacturing

LO4 Examine workplace activities in a semiconductor manufacturing environment for assessment, minimisation and management of risk.

Essential Content

LO1 **Recognise the role and applicability of Health and Safety legislation and other guidelines in semiconductor manufacturing**

Health and Safety, core considerations:

The nature of risk and the costs of unsafe working. Recognising responsibility for safe working at individual, corporate and state levels and the consequences of non-compliance. General and specific risk, cultural and social responses to risk. Concept of personal responsibility for the Health and Safety of self and others in the workplace. Role of employee within company management of Health and Safety. Company structures for the management, training and updating of Health and Safety requirements and regulations, actions after Health and Safety breaches or incidents. End of life risks for manufactured products and process discharge.

Health, Safety and Environmental Procedures and Standards:

Mandatory compliance with UK, European and international health and safety regulations as they apply to the semiconductor manufacturing working environment, working practices and the provision and use of personal protection equipment (PPE)

e.g. Health and Safety at Work Act 1974, Management of Health and Safety Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER) 1998, Control of Substances Hazards to Health (COSHH) 2002, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Personal Protective Equipment at Work Regulations 1992, Electricity at Work Regulations 1989, Health and Safety (First Aid) Regulations 1981, Control of Pollution (Amendment) Act 1989, BPD/R: Biocidal Products Directive/Regulations (BPD/R), CDG: Carriage of Dangerous Goods, CHIP: Chemicals (Hazard Information and Packaging for Supply), CLP: Classification, Labelling and Packaging and Substances and Mixtures (CLP Regulation), adopting in the EU the Globally Harmonised System (GHS)

The role and powers of the Health and Safety Executive in the UK.

Company and process specific Health and Safety Requirements and Systems:

Company safety rules and systems, accident books, provision and maintenance of safety policies, codes of practice and safety audits. Incident reporting and review. Ongoing training of staff, systems for reviewing and managing health and safety, safety circles, safety share, safety committee systems

Process specific issues; suppliers' guidance for the handling of raw materials, awareness of atmospheric, temperature and process parameters for safe working

Semiconductor Process; infrastructure in the clean room, e.g. life safety systems for gas and chemical detection, oxygen depletion within the fabrication infrastructure, multiple safety interlocks and fail safe devices on tooling.

LO2 Describe the different cleanroom arrangements and their relevance to semiconductor manufacturing

Semiconductor manufacturing environment:

Effects of the presence of the smallest particles of dust, grease or production debris on the manufacturing process. Detrimental effect on production operative's health of the liquid or gaseous discharge from the manufacturing process, need to carry away and efficiently filter such discharge. Requirement to create controlled and safe working environments.

Cleanrooms:

Rational; the cleanroom as a space in which the level of particulate contamination is controlled within set limits. Requirement to control temperature, humidity, air flow patterns and pressure to minimise the introduction, generation and retention of particles within the cleanroom. Classification of cleanrooms by permitted density of particle size per m^2, (1-5.μm particles per m^3), effect and scope of the International Organisation for Standardisation (ISO) classification ISO 14644-1:2015(en) to ISO 14644-9:2012 Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle connection

Construction of cleanroom; requirement for airtight construction (to allow use of positive pressure within the cleanroom) with easy to clean internal surfaces. Bay, Chase and Ballroom configuration of cleanrooms. Requirements of furniture and fittings used in cleanrooms. Importance of Electrostatic Discharge (ESD) in a cleanroom

Atmospheric management; requirement for high air exchange rates, rapid air velocities and directed airflows to minimise particle concentration. Positive pressurisation levels, around 10 to 25 Pa, higher than adjacent areas, more air in than out process. Negative pressure exceptions in areas working with specific (hazardous) materials. Air filtration efficiency requirements, use of High Efficiency Particulate Air (HEPA) diffusion filters to remove 99.97% of contaminants of 0.3 microns and above. Leak testing, recovery rates, comfort and pressurisation levels. Use of gas detection systems, oxygen monitors and oxygen analysers when inert gases are used. Requirements for comprehensive fire safety systems

Testing and certification requirements; relevant national European Union (EU) and international standards. **International Organization for Standardization** (ISO), ISO 14644-1:2015(en) to ISO 14644-9:2012 Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle connection, EU Good Manufacturing Practice (GMP) classification, ISO 14698-1:2003 Cleanrooms and associated environment – Bio-contamination controls – Part 1: General principles and methods, **American National Standards Institute** (ANSI)

Airborne particle concentration testing, airflow readings and Clean Testing and Certification Board (CTCB), CTCB-1 testing, certification and validation. Importance of working within Good Manufacturing Practice (GMP) requirements for semiconductor manufacture.

LO3 **Investigate the toxicity of the materials and processes employed in semiconductor manufacturing**

Sources of toxicity:

Potential airborne emissions from the manufacturing process including; toxic, reactive and hazardous gases, organic solvents and particulates. Chemicals and gases present include; arsenic, arsine, cadmium, gallium arsenide; hydrochloric, hydrofluoric, phosphoric, nitric and acetic acids; acetone, isopropanol, N-butyl acetate, trichloroethylene, and xylene solvent vapours; Thin film metals including, copper, nickel, iron, chromium, tin, palladium, gold and lead as solder. Also reference precursor materials for Low-k and High-k dielectrics, CMP slurries, ancillary chemicals, wet processing chemicals, photoresists, atmospheric and specialty gasses

Leaks from nitrogen or argon storage tanks. Nitrogen as an oxidation preventative for both selective soldering and convection reflow soldering. Argon use in the sputtering deposition process

Presence of above chemicals in liquid and solid waste, possibility and control of environmental pollution.

Effects of toxicity:

Risk of carcinogenic outcome to extreme exposure, risk to the unborn child, headache, nose, throat, lung and eye irritation, vomiting, confusion, diarrhoea and irregular heartbeat have been noted as short-term reactions to exposure of toxic agents.

Legislation specific to working with toxic materials:

Control of Substances Hazards to Health (COSHH) 2002, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Health and Safety (First Aid) Regulations 1981, Personal Protective Equipment at Work Regulations 1992, Control of Pollution (Amendment) Act 1989.

Mitigation methods:

Controlled and filtered atmospheres in manufacturing areas. Regular and effective maintenance of air control systems with appropriate certification

Correct use of appropriate personal protective equipment (PPE) including; over suits, gowns, coats, hoods, face masks (Yashmaks), caps, helmets, overshoes or boots, safety goggles, visors and gloves. Correct use of appropriate hazard protection equipment including; breathing apparatus, full protective suits and gloves

Correct fitting and use of PPE, safe removal, laundering or disposal of contaminated PPE. Prompt reporting of illness or workplace distress

Use of correct cleaning methods for contaminated work areas. Strict adherence to maintenance schedules

Controlled removal and disposal of contaminated waste and scrap items.

LO4 **Examine workplace activities in a semiconductor manufacturing environment for assessment, minimisation and management of risk.**

Risk Assessment:

Rationale for risk assessment. Risk assessment template design, identification of areas to be assessed, completion of risk assessments using the five-step approach; principle hazards, who is at risk, evaluate level of risk and adequacy of mitigation, record findings, review assessment. Risk rating; matrix production e.g. low risk, moderate risk, substantial risk, high risk. Frequency and severity of incidence, evaluation of the rate of occurrence e.g. improbable, possible, occasional, frequent, regular, common; evaluation of severity e.g.; definitions of consequence; level of injury sustained, e.g. graded as trivial, minor, major, multiple major, death, multiple death, types of risk assessment, e.g. Hazard and Operability (HAZOP), qualitative and quantitative risk assessment.

Adherence:

Ensuring adherence to risk assessment; regular inspections, spot checks, safety groups.

Accident and incident reporting:

Need for accident and incident reporting. Design and completion of accident and incident reporting forms. Collection of evidence e.g.; data, fatigue charts, lighting levels, temperature, time of day. Management responsibility and action on accident and incident reporting.

Action from accident and incident reporting:

Use of accident and incident reporting to identify trends and high-risk areas/processes, evaluation of evidence to support the likelihood of, or reoccurrence of, a risk; use of statistical data to assist modification of working process and provision of training in response to findings.

Emergency evacuation:

The importance of evacuation procedures in semiconductor manufacturing. Requirement for voice evacuation, visual and acoustic evacuation systems. Evacuation procedures developed from risk assessments and safety audits. Health and safety training developed from risk assessment and safety audits.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Recognise the role and applicability of Health and Safety legislation and other guidelines in semiconductor manufacturing		
P1 Detail key requirements of the relevant health and safety regulations as they apply to semiconductor manufacturing processes. **P2** Show how health and safety policies and company specific guidance are used to reduce risk.	**M1** Review the nature of risks to health and safety in semiconductor manufacturing processes engineering.	**D1** Assess how employee engagement can reduce risk in semiconductor manufacturing.
LO2 Describe the different cleanroom arrangements and their relevance to semiconductor manufacturing		
P4 Describe the features of semiconductor manufacture that make the use of cleanrooms essential. **P5** Identify the environmental parameters that must be managed to ensure safe and effective semiconductor manufacturing in cleanrooms.	**M2** Compare how airborne contaminants are removed from a cleanroom used within the semiconductor manufacturing industry.	**D2** Evaluate how working within Good Manufacturing Practice (GMP) guidelines can improve the semiconductor manufacturing process.

Pass	Merit	Distinction
LO3 Investigate the toxicity of the materials and processes employed in semiconductor manufacturing		
P6 Identify the primary sources of toxicity present in the semiconductor manufacturing process. **P7** Describe the type and fit required for personal protection equipment suitable for use in controlled atmosphere situations or processes using inert gas shielding.	**M3** Summarise the relevant Health and Safety legislation as it applies to the use of toxic substances in semiconductor manufacturing.	**D3** Analyse the issues around the safe disposal of contaminated waste from semiconductor manufacturing to minimise risks of environmental pollution.
LO4 Examine workplace activities in a semiconductor manufacturing environment for assessment and prevention of risk.		
P8 Explain the rationale behind carrying out risk assessments within the semiconductor manufacturing environment. **P9** Detail the workplace activities in a semiconductor manufacturing environment to prevent risk.	**M4** Develop an emergency action plan and evacuation procedure for a given area of the semiconductor manufacturing process.	**D4** Carry out a full risk assessment on a discrete area of the semiconductor manufacturing process and evaluate its intended effectiveness.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Balasinski A. (2012) *Integrated Circuit Design for Manufacturability*. CRC Press.

CAMPBELL S.A. (2001) *The Science and Engineering of Micro-electronic Fabrication*. Oxford University Press.

Geng H. (2017) *Semiconductor Manufacturing Handbook*. 2nd Ed. McGraw-Hill.

Kalpakjian S. and Schmid S.R. (2014) *Manufacturing Engineering and Technology.* 7th Ed. Pearson

May G.S. and Spanos C.J. (2006*) Fundamentals of Semiconductor Manufacturing and Process Control.* Wiley.

Reinhardt K.A. and Reidy R.F. (2010) *Handbook of Cleaning in Semiconductor Manufacturing: Fundamental and Applications*. Wiley.

Reinhardt K. and Kern W. (2018) *Handbook of Silicon Wafer Cleaning Technology.* 3rd Ed. Elsevier.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Semiconductor Manufacturing

IEEE Transactions on Semiconductor Manufacturing

Websites

hse.gov.uk	Health and Safety Executive Chemical related legislation (General reference)
iso.org	International Organisation for Standardisation Cleanrooms and associated controlled environments standards (General reference)

Links

This unit links to the following related units:

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 4041: Aircraft Aerodynamics

Unit Code: D/651/0772

Level: 4

Credits: 15

Introduction

The thrill of designing and building heavier than air machines that mimic bird flight, has always been a source of inspiration to early aviation enthusiasts – their ultimate aim was to produce a heavier than air machine that would not only fly but could be controlled, manoeuvred and then landed safely. The aims of those early day enthusiasts are the same as those for latter day aeronautical engineers, where although far more complex, the study of aircraft aerodynamics is the essential science that underpins aircraft flight.

This unit introduces students to the atmosphere in which aircraft fly and the scientific principles that underpin flight theory; the aerodynamic forces that are generated throughout all phases of flight and the effect they have on the aircraft airframe; how a study of the nature of high-speed air flows lead to the necessary design features for aircraft that fly at supersonic velocities and how aircraft are stabilised and controlled during flight.

Topics included in this unit are: the atmosphere, aerodynamic principles, flight forces and their effect, high speed airflows, design features of high speed aircraft, stability and control.

On successful completion of this unit students will be able to examine the properties of the atmosphere and aerodynamic principles and apply them to aircraft flight; learn about the generation, nature, and effects of aerodynamic forces during flight; study the nature of high-speed airflows and the need for high speed aircraft design features; and the nature and methods used to stabilise and control aircraft.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine standard atmospheric properties and aerodynamic principles affecting flight

LO2 Describe the nature and effect of forces that act on aircraft in flight

LO3 Demonstrate the nature of high-speed airflows and their effect on fixed wing aircraft design

LO4 Investigate the nature and methods used to control and stabilise fixed-wing aircraft.

Essential Content

LO1 **Examine standard atmospheric properties and aerodynamic principles affecting flight**

The standard atmosphere:

The composition of the air and different layers of the real atmosphere

Nature of the International Standard Atmosphere (ISA): need, function, definitions of standard properties

Use tables and hydrostatic temperature lapse rate and state equations to determine the changing parameters (temperature, pressure, density, viscosity) of the air in the ISA, with changing altitude.

Aerodynamic principles:

Airflow definitions; laminar, turbulent, compressible, and incompressible flows

Nature of low-speed airflow over aerofoil sections; aerofoil terminology, viscosity effects, boundary layer, aerodynamic shape, pressure, and flow changes with differing angle of attack (AOA) and airspeeds

Determine experimentally and analytically lift ($L=C_L 1/2\rho V^2 S$) and drag ($D=C_D 1/2\rho V^2 S$) forces over aerofoil sections subject to low-speed airflows and how lift and drag forces interact over aircraft wings and the significance of the lift/drag ratio as a measure of performance

Define and use the continuity, energy, Bernoulli, isentropic and Reynolds number fluid flow equations to determine low speed airflow parameters.

LO2 Describe the nature and effect of forces that act on aircraft in flight

Factors effecting flight forces:

Wing plan form geometry and its effects on lift and drag production

Boundary layer effects on lift and drag and its control

Atmospheric events: severe air turbulence, frost and ice accretion

Aero-elastic effects: wing torsional divergence, controls reversal and flutter.

Nature of flight forces:

Lift/weight, drag/thrust, forces and couples, line of action, airspeed

Determine gravitational and aerodynamic forces during, straight and level flight, steady coordinated turn, climbing and diving flight, glide, pull-up, push-over manoeuvres

Manoeuvre envelope and structural limits, interpretation, and consequences of exceeding limits.

LO3 **Demonstrate the nature of high-speed airflows and their effect on fixed wing aircraft design**

Nature of high-speed airflows:

Speed of sound definition and relationship for a perfect gas ($a=\sqrt{\gamma RT}$), relationship between speed of sound and Mach number ($M=V/a$)

Nature of transonic and supersonic airflows over aerofoil sections, compressibility effects, shockwave formation, the shock stall, airflow parameters across the shockwave, Mach cone.

Effects on fixed-wing aircraft design:

Problems with flight in the transonic range, shock stall effects, pitching and buffeting, transonic drag rise at constant lift, effect on flow rate, pressure, lift, drag, pitching moment and aerodynamic centre

Transonic flow and aircraft design: conventional, thin and supercritical wing sections, swept wings, load distribution, wing tip flow and design, transonic airflow over fuselage/wing and use of area ruling

Supersonic flow and aircraft wing plan form design, un-swept and swept wings, leading and trailing edge sweep back, swing-wing, swept forward wings.

LO4 Investigate the nature and methods used to control and stabilise fixed-wing aircraft

Flight control:

Control requirements, aircraft axes, roll, yaw, pitch, six degrees of freedom

Primary conventional control surfaces: aileron, elevator and rudder, servo-tabs, balance-tabs, trim-tabs, and q-feel control

Secondary controls: slab, all-moving tailplanes, canard surfaces, vee-tail, spoilers, high speed ailerons, flaperons, elevons

Lift augmentation and drag inducing devices (leading edge devices, trailing edge devices, and wing surface device): flaps, slats, slots, vortex generators, wing fences, winglets, spoilers, and airbrakes.

Aircraft stability:

Nature of static and dynamic stability: reaction to a disturbance for stable, neutrally stable, and unstable bodies

Longitudinal static stability: trim, use of tailplane, pitching moments and significance of centre of pressure movement and centre of gravity limits, lateral static stability, yawing, rolling, stability methods and use of anhedral for inherent instability

Longitudinal dynamic stability: nature and damping methods for short period pitching oscillations and phugoid motion, lateral dynamic stability, nature and damping methods for spiral mode and Dutch roll.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine standard atmospheric properties and aerodynamic principles affecting flight		**D1** Analyse the properties of the air in the ISA, including changing altitude and the relationship between fluid flow equations and the generation of lift and drag affecting flight.
P1 Examine the nature of the ISA and the changes that take place to the properties of the air with changing altitude. **P2** Assess, using theoretical calculations and wind tunnel experimental results how lift and drag forces are generated from low-speed airflows over aerofoil sections.	**M1** Explore quantitatively, how the properties of the air in the ISA change with altitude and the differences between the lift and drag forces found from theoretical calculations and from wind tunnel experimental results.	
LO2 Describe the nature and effect of forces that act on aircraft in flight		
P3 Describe how wing planform, the boundary layer, atmospheric events and aeroelasticity, effect the generation and distribution of lift and drag. **P4** Calculate the forces that act on aircraft in straight and level flight and during manoeuvres.	**M2** Explore, using theoretical calculations the nature of flight forces during manoeuvres, how these forces are affected by geometrical and external factors and the significance of the manoeuvre envelope in protecting the aircraft structure.	**D2** Evaluate the effect and nature of flight forces on the aircraft airframe throughout all phases and conditions of flight, including the nature and significance of the load limits within the manoeuvre envelope that protect the aircraft structure.

Pass	Merit	Distinction
LO3 Demonstrate the nature of high-speed airflows and their effect on fixed wing aircraft design		
P5 Demonstrate the relationship between the speed of sound and Mach number and the nature of transonic and supersonic airflows over aerofoil surfaces. **P6** Describe the problems with aircraft flight in the transonic range and the resulting design features for aircraft that fly at transonic and supersonic speeds.	**M3** Explain transonic and supersonic airflows over aerofoil surfaces and the resulting problems and design features for aircraft that fly at transonic and supersonic speeds.	**D3** Analyse transonic and supersonic airflows over aerofoil surfaces, and the resulting problems and design features and their interrelationship, for aircraft that fly at transonic and supersonic speeds.
LO4 Investigate the nature and methods used to control and stabilise fixed-wing aircraft		
P7 Explore the nature and operation of aircraft primary controls and secondary controls, lift augmentation, and drag inducing devices. **P8** Investigate the nature of static and dynamic stability and how aircraft are stabilised about their axes of rotation.	**M4** Illustrate aircraft control and stabilisation devices and methods and their interaction.	**D4** Analyse aircraft control and stabilisation devices and methods, and their interaction, for aircraft that fly in the transonic and supersonic speed range.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson J.D. (2024) *Fundamentals of Aerodynamics*. 7th Ed. McGraw Hill.

Anderson Jr J. D. (2016) *Introduction to Flight*. 8th International Student Ed. McGraw-Hill.

Barnard R. H. and Philpott D. R. (2010) *Aircraft Flight*. 4th Ed. Pearson.

Clancy L.J. (2006) *Aerodynamics.* Sterling Book House.

Collicott S.H., Valentine D.T., Houghton E.L. and Carpenter P.W. (2024) *Aerodynamics for Engineering Students*. 8th Edition. Elsevier.

Dingle L. and Tooley M. (2013) *Aircraft Engineering Principles*. 2nd Ed. Routledge.

Kuethe A. M. and Chow C.Y (1997) *Foundations of Aerodynamics: Bases of Aerodynamic Design.* 5th Ed. Wiley.

Journals

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Aerospace

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

International Journal of Aerospace Engineering

Journal of Aircraft

Journal of Aerospace Engineering

Journal of Aerospace Information Systems

Journal of Propulsion and Power

SAE International Journal of Aerospace

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4045: Turbine Rotary Wing Mechanical and Flight Systems

Unit 5027: Aircraft Propulsion Principles and Technology.

Unit 4042: Aircraft Electrical Power and Distribution Systems

Unit Code: **F/651/0773**

Level: **4**

Credits: **15**

Introduction

All modern aircraft make extensive use of electrical power and the systems that generate and distribute this power are becoming increasingly more complex. Aircraft electrical power can be derived from a variety of different sources, but it must then be distributed to the aircraft services that rely on that power, including engine starting, lighting, air conditioning, flight controls, braking systems de-icing, galley services and a wide variety of essential avionic systems.

Primary sources of aircraft electrical power include batteries, DC and AC generators. In addition to these internal sources of power, aircraft also have the ability to be connected to external ground power units (GPU). For large transport aircraft, the use of ground power is essential during maintenance and whilst an aircraft is being loaded or fuelled. Larger aircraft may also have the benefit of an auxiliary power unit (APU), which can be used for starting the aircraft's main engines as well as providing power for essential systems. Transformer rectifier units (TRU) convert the AC power originating from the engine, APU, and the GPU to DC power of appropriate voltage for use by various electrical components of the aircraft.

This unit will provide the student with a comprehensive introduction to the generation and distribution of electrical power in an aircraft. Different methods of generating, supplying, distributing, and managing the electrical power required by typical modern aircraft will also be investigated, together with the purpose and operation of related components and sub-systems such as contactors, regulators, protection circuits and bus power control units (BPCU).

On successful completion of this unit students will be able to interpret electrical power schematic diagrams, identify the function of components and sub-systems, and understand the rationale and technology used for distributing power to system-critical components.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe internal and external sources of aircraft power and their application in modern civil and military aircraft

LO2 Discuss the principles and application of aircraft DC power sources

LO3 Explain the principles and application of aircraft AC power sources

LO4 Illustrate the function and operation of the components and sub-systems used in aircraft electrical power distribution systems.

Essential Content

LO1 **Describe internal and external sources of aircraft power and their application in modern civil and military aircraft**

Primary and secondary sources of aircraft power:

Batteries DC generators, AC generators (engine driven), APU driven generators

Ram air turbine (RAT).

External sources of aircraft power:

External DC and AC supplies

Ground power units (GPU).

Aircraft applications of electrical power:

Services needed for flight

Essential services, non-essential services

Engine starting

Lighting. Air conditioning

Avionic systems (radio communication, navigation, weather radar, anti-collision)

Galley services.

Case studies on latest advancements:

Modern aircrafts with increasing use of electrical power (e.g., braking systems, flap actuation and safety), electric aircraft systems and architecture.

LO2 **Discuss the principles and application of aircraft DC power sources**

Batteries:

Battery types and characteristics (lead-acid, nickel-cadmium, nickel-metal hydride, lithium)

Battery charging and venting.

DC generators:

DC generator principles

Series, shunt, and compound wound generators

Voltage regulation (vibrating contact, carbon pile, solid-state).

LO3 **Explain the principles and application of aircraft AC power sources**

AC generators:

Three-phase AC principles

Star and delta-connected sources and loads

Power and power factor

Three-phase AC generators

Integrated drive generators (IDG)

Frequency wild generating systems

Constant frequency generating systems.

LO4 **Illustrate the function and operation of the components and sub-systems used in aircraft electrical power distribution systems**

Components and sub-systems:

Transformers

Transformer/rectifier units (TRU)

Inverters

Relays and contactors

Current transformers (CT)

Protection (over-voltage and over-current)

Power factor correction

Harmonic suppression.

Power distribution:

Aircraft electrical bus systems

Load sharing techniques (split bus, bus transfer, parallel load distribution)

Bus-tie breakers (BTB)

Essential services bus

Phase protection

Differential current protection

Load shedding

External GPU connection

Power monitoring.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe internal and external sources of aircraft power and their application in modern civil and military aircraft		
P1 Classify aircraft systems as essential, needed for flight, and non-essential. **P2** Describe available sources of power as batteries, DC generators, AC generators (engine driven), AC generators (APU driven) and external ground power. **P3** Compare between different types of aircraft (small and large) load in terms of supply voltage, current demand, and duty cycle.	**M1** Explain the need for multiple sources of aircraft power. **M2** Explain the need for an auxiliary power unit (APU) in a large aircraft.	**D1** Analyse a typical transport aircraft (civil or military) in terms of its electrical supply requirements and the available power sources.
LO2 Discuss the principles and application of aircraft DC power sources		
P4 Discuss the characteristics of lead-acid, nickel-cadmium, nickel-metal hydride, and lithium batteries for use in aircraft. **P5** Outline and describe the construction of an aircraft DC generator. **P6** Outline different types of DC voltage regulator, including vibrating contact, carbon pile and solid-state.	**M3** Explain the principle of operation of an aircraft DC generator. **M4** Illustrate the characteristics of series, shunt and compound wound aircraft DC generators. **M5** Explain the need to regulate the DC output from an aircraft generator.	**D2** Analyse the performance of an aircraft DC voltage regulator over a range of different driveshaft speeds and load currents.

Pass	Merit	Distinction
LO3 Explain the principles and application of aircraft AC power sources		
P7 Explain the construction of an aircraft AC generator. **P8** Describe, with the aid of labelled circuit diagrams, star and delta connected three-phase AC sources and loads. **P9** Describe, with the aid of a labelled diagram, the construction and electrical arrangement of an integrated drive generator (IDG).	**M6** Analyse the advantages of three-phase AC power when compared with single-phase AC systems. **M7** Illustrate the advantages and disadvantages of frequency wild and constant frequency AC generating systems.	**D3** Evaluate the performance of a three-phase AC generating system over a range of different load currents and load power factors.
LO4 Illustrate the function and operation of the components and sub-systems used in aircraft electrical power distribution systems		
P10 Illustrate the need for, and function of, a DC to AC inverter. **P11** Illustrate the need for, and function of, a power factor corrector. **P12** Illustrate the need for, and function of, a harmonic suppressor. **P13** Outline the need for, and function of, a transformer/rectifier unit (TRU). **P14** Outline the need for, and function of, an essential services bus.	**M8** Justify the arrangement of an aircraft electrical bus distribution system. **M9** Explain, with the aid of a labelled diagram, the principle of the current transformer. **M10** Discuss, with the aid of a labelled diagram, the principle of power factor correction. **M11** Explain the function of a bus power control unit (BPCU).	**D4** Analyse the performance of an aircraft electrical bus distribution system under varying conditions, including loss or failure of one or more primary or secondary power sources.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Eismin T. (2013) *Aircraft Electricity and Electronics*. 6th Ed. McGraw-Hill Education.

Tooley M. and Dingle L. (2013) *Aircraft Engineering Principles.* Taylor & Francis Aerospace and Aviation Engineering.

Tooley M. and Wyatt D. (2018) *Aircraft Electrical and Electronic Systems*. 2nd Ed. Butterworth-Heinemann.

Collinson R.P.G. (2014) *Introduction to avionic systems*. Dordrecht: Springer.

Eismin T.K. (2011) *Avionics: systems and troubleshooting: a practical guide to advanced avionics.* Weyers Cave, Va: Avotek.

Moir I. (2013) *Civil avionics systems*. Chichester: Wiley.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Aerospace Science and Technology

Electrical Power Systems Research

Green Energy and Intelligent Transportation

The Electricity Journal

AIAA journal

Links

This unit links to the following units:

Unit 4016: Instrumentation and Control Systems

Unit 4019: Electrical and Electronic Principles

Unit 4043: Airframe Mechanical Systems

Unit Code: K/651/0776

Level: 4

Credits: 15

Introduction

When aircraft take off and land they require an undercarriage, wheels and brakes to allow them to accelerate and decelerate along the runway. During flight, aircraft are manoeuvred using flight controls, fuel is continuously supplied to the engines for propulsive power, personnel are kept safe and comfortable in a pressurised air-conditioned environment and emergency protection systems ensure the safety of the aircraft and personnel, no matter what the weather or the emergency situation.

This unit introduces students to the design and operation of airframe mechanical systems (hydraulic power, landing gear, flight control systems, environmental control systems, protection systems and airframe fuel systems) and how these systems contribute to the safety of personnel, the aircraft airframe and its engines.

On successful completion of this unit, students will be able to examine how the design and operation of hydraulic systems and services and environmental control systems contribute towards safe aircraft flight and passenger and crew comfort and safety. They will also be able to determine how the layout and operation of protection and airframe fuel systems contribute to the safety of the aircraft, personnel, and engine operation.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Analyse how the design and operation of hydraulic systems contribute to safe flight

LO2 Examine how the design and operation of cabin environmental control systems contribute to the safety of the airframe and personnel

LO3 Investigate how the layout and operation of protection systems contribute to safe flight

LO4 Explain how the layout and operation of airframe fuel systems ensures a continuous safe supply to the aircraft engines.

Essential Content

LO1 **Analyse how the design and operation of hydraulic systems contribute to safe flight**

Hydraulic power supply systems:

Hydraulic fluids: characteristics, types, mineral and phosphate ester-based oils, identification, sources, and consequences of contamination

System design requirements: power source, fluid storage, actuation, conditioning, filtration, directional, flow and temperature control, distribution, emergency/alternative provision system operation under normal and emergency conditions

Design and operation of power supply systems and components: function and operation of reservoirs, pumps, actuators, fluid pressure, flow and direction control valves, heat exchangers and fluid plumbing, hydraulic panel indications and warnings, under normal and emergency supply conditions

Landing gear systems:

Design and operation of landing gear and retardation components: single and multi-bogies, undercarriage bay layout, shock absorbers, wheels, tyres, brake units, steering mechanisms

Design and operation of extension/retraction and retardation systems: hydraulic directional control and sequencing, braking, anti-skid, cockpit/cabin indications and warnings, emergency provision

Hydraulically powered flight control systems:

Design and operation of: primary flight control systems, powered flight control units (PFCU), leading and trailing edge lift augmentation systems and lift reduction systems, under normal and emergency conditions

Introduction to fault finding in hydraulic power supply systems

Case studies:

Industry examples (e.g., analytical design aspects, safety case studies)

LO2 **Examine how the design and operation of cabin environmental control systems contribute to the safety of the airframe and personnel**

Pneumatic supplies:

Requirements: air supply source, storage, conditioning, directional, flow and temperature control and distribution

Services: air-conditioning, pressurisation, thermal anti-icing, engine starting, door sealing and pitot-static system

Air supply sources and control: gas turbine engine and auxiliary power unit (APU) bled air, piston engine compressor, blower and receiver air supplies, ram air, ground cart air, control via ducts, louvres, trunking, check valves flow and pressure control valves

Cabin air-conditioning and pressurisation systems:

Requirements for conditioned and pressurised cabin air

Function and system operation of cabin/cockpit air-conditioning components: air mixing plenum chambers, recirculation fans, temperature control valves and duct stats, filters, humidifiers, water separators, air-conditioning pack, cold air unit (CAU)

Design and operation of air-conditioning system: mixing, temperature and humidity control and recirculation of conditioned air, under normal and emergency conditions

Function and operation of cabin pressurisation system components: pressure controllers, discharge valves, relief valves, warning and indicating devices

Design and operation of cabin pressurisation system: cabin pressure control cycles, discharge methods, emergency provision, warnings and indications

Oxygen systems:

Need, design and operation of aircraft oxygen systems and components under normal and emergency conditions: crew and cabin therapeutic walk-round bottles, oxygen generators chemical and molecular sieve, cabin and crew oxygen storage, distribution and regulation, emergency drop-down masks

Health and safety procedures and compliance within the context: Standard Operating Procedures (SOPs), documentation recording systems, documentation control processes and procedures such as format, location, access, authorisation; risk assessment, implications on safety, quality and delivery if they are not adhered to.

LO3 Investigate how the layout and operation of protection systems contribute to safe flight

Aircraft ice protection systems:

Nature of ice formation and its effect on aircraft safety and operation

Ice detection devices function and activation: probes, vanes, electronic and mass activation

Layout and operation of pre-emptive anti-icing systems: electrical, hot air, chemical, ground anti-icing

Layout and operation of reactive de-icing systems: pneumatic, electromagnetic-impulse, chemical

Fire detection and extinguishing systems:

Layout and operation of fire detection components and circuitry: unit detectors and detector alarm and test circuits, continuous loop detectors, resistance and pneumatic detectors and control unit

Operation of smoke and fire detectors

Type and meaning of flight-deck and cabin warnings: fire warning panel, location indicators, lights, claxons, overheat indicators

Classes of fire A, B, C and D and type of extinguishing agent/s to be used on each

Layout and operation of plumbed extinguisher systems, components and handheld appliances: extinguisher bottles, discharge valves, cartridges, plumbing, check valves, bottle pressure and discharge indicators, pilot and automatic operation of extinguishant actuation system

LO4 **Explain how the layout and operation of airframe fuel systems ensures a continuous safe supply to the aircraft engines**

Aircraft engine fuels and fuel system components:

Properties, use and handling of aircraft fuels: aviation gasoline (AVGAS), aviation jet turbine kerosene JETA1 (AVTUR) and wide cut jet turbine fuel JET B (AVTAG), type and function of fuel additives, handling precautions

Fuel system component description and function: fuel tanks, fuel booster and transfer pumps, transfer valves, non-return and vent valves, plumbing, fuel quantity sensors, gauges, warning and indicating sensors, heat exchangers, built-in component redundancy

Layout and operation of airframe fuel systems:

Fuel tank layout, balance and trim tanks, cross-feed and alternative provision

Fuel system operating modes: fuel feed, pressurisation, inerting and transfer; fuel jettison, venting, refuelling and de-fuelling (e.g., air-to-air), relevant considerations (e.g., spark prevention, effects of static charge to airflow friction).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse how the design and operation of hydraulic systems contribute to safe flight		
P1 Explain the system requirements, fluid properties, design and operation of aircraft hydraulic power supply systems and the function of their components, operating under normal and emergency conditions. **P2** Analyse the design and operation of aircraft landing gear and hydraulically powered flying control systems and the function of their components, operating under normal and emergency conditions.	**M1** Illustrate the design features and operation of hydraulic, power supply, landing gear and flying control systems and their major components, operating under normal and emergency conditions.	**D1** Evaluate the design and operation of hydraulic, power supply, landing gear and flying control systems and their major components while operating under normal and emergency conditions, assessing the contribution made by each system to safe flight.
LO2 Examine how the design and operation of cabin environmental control systems contribute to the safety of the airframe and personnel		
P3 Examine pneumatic system requirements and the control and distribution of air supplies to the aircraft services. **P4** Discuss the design and operation of oxygen, air-conditioning and pressurisation systems and the function of their components under normal and emergency operating conditions.	**M2** Explain the design and operation of oxygen, pneumatic air supply, air-conditioning and pressurisation systems and components under normal and emergency operating conditions.	**D2** Analyse the design and operation of oxygen, pneumatic air supply, air conditioning and pressurisation systems and components under normal and emergency operating conditions, assessing the contribution made by each system to the safety of the airframe and personnel.

Pass	Merit	Distinction
LO3 Investigate how the layout and operation of protection systems contribute to safe flight		
P5 Discuss the layout and operation of aircraft ice protection systems and function of system components, under normal and emergency operating conditions. **P6** Investigate the layout and operation of aircraft fire detection and extinguishing systems and function of their components under normal and emergency operating conditions.	**M3** Illustrate the layout and operation of ice protection and fire detection and extinguishing systems and associated components under normal and emergency operating conditions.	**D3** Analyse the layout and operation of ice protection, fire detection and extinguishing systems and associated components under normal and emergency operating conditions, assessing the contribution made by each system to safe flight.
LO4 Explain how the layout and operation of airframe fuel systems ensures a continuous safe supply to the aircraft engines		
P7 Discuss the properties, use and safe handling of aircraft fuels and the nature and function of airframe fuel system components. **P8** Explain the layout and operation of airframe fuel systems for all operating modes.	**M4** Illustrate the layout and operation of airframe fuel systems and their components for all operating modes, identifying the contribution made by the system to the continuous safe supply of fuel to the engines.	**D4** Analyse the layout and operation of airframe fuel systems and their components for all operating modes, assessing the contribution made by the system and its components to the continuous safe supply of fuel to the engines.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

MOIR I. and Seabridge A. (2008) *Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration (Aerospace Series)*. 3rd Ed. Chichester: Wiley.

Parr A. (2011) *Hydraulics and Pneumatics: A technician and engineers guide*.
3rd Ed. Imprint Butterworth Heinemann Ltd.

sterkenburg R. and Wang P.H. (2021) *Standard Aircraft Handbook for Mechanics and Technicians*. 8th Ed. McGraw-Hill.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Aerospace

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

International Journal of Aerospace Engineering

Journal of Aircraft

Journal of Aerospace Engineering

Journal of Aerospace Information Systems

Journal of Propulsion and Power

SAE International Journal of Aerospace

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 5027: Aircraft Propulsion Principles and Technology

Unit 5031: Advanced Composite Materials for Aerospace Applications.

Unit 4044: Composite Materials for Aerospace Applications

Unit Code: R/651/0779

Level: 4

Credits: 15

Introduction

The aerospace market combines both the civil and the military sectors. The civil market is highly competitive, and cost driven, whilst cuts in military funding have changed the drivers from purely performance to cost and performance. Composite materials are now key in the manufacture of modern aircraft structures and components, combining exceptional fatigue properties with the ability to form complex shapes, whilst reducing weight, which offers such benefits as increased fuel efficiency and additional payload. It is no wonder that the aerospace market is the lead user of composites.

This unit explores what makes up a composite material and how the properties can be tailored to achieve the required performance. Students will appreciate the different manufacturing techniques used in aerospace and what influences the choices made by designers and manufacturers. A key part of composites in service is how damage is identified, assessed, and rectified. This unit looks at common causes of defects, methods of assessment of defects and common repairs of composite structures used in aerospace.

The unit is a mix of theoretical and practical work and is designed to give learners a holistic understanding of composites used in aerospace. Previous knowledge of composites is not assumed, but a background in engineering would be advantageous. On successful completion of this unit, learners will be able to describe in detail how composites are produced, maintained, and repaired in aerospace applications.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Distinguish between the different constituents of composite materials used in aerospace engineering

LO2 Compare key manufacturing processes used in aerospace composite production

LO3 Correlate defects, their identification and evaluation

LO4 Review repair methods and techniques stated in Structural Repair Manuals (SRM) or Aircraft Repair Manual (ARM) from the Design Authority (DA).

Essential Content

LO1 **Distinguish between the different constituents of composite materials used in aerospace engineering**

Fibres:

Types of fibres used, the benefits of the available sub-types of fibres, sizing treatments and interface

Reinforcement:

How the fibres are put together to form a fabric and the benefits of the different weave styles available

How the reinforcements are used to tailor the strength of the component.

Matrix:

Role of the matrix, difference between thermoset and thermoplastic and how to select

Advantages and disadvantages of the four main aeronautical thermoset matrices used (epoxy, phenolic, bismaleimide, cyanate ester), as well as metal and ceramic matrices. Fibre volume fraction, glass transition temperature, post curing.

Core materials:

Types of core materials used in aeronautical structures and their benefits

Complexities of manufacturing with core materials, limitations of core materials (galvanic corrosion).

Non-structural materials:

Lightning strike protection, paints, coatings.

Mechanical properties:

Determine the elastic properties of a unidirectional composite lamina from the properties of the fibre and the matrix using mechanics of materials approach.

LO2 **Compare key manufacturing processes used in aerospace composite production**

Pre-preg lay up:

Processing limitations, nomenclature, laminate theory (balanced and symmetrical plies), tooling and tooling features, release agent and consumables.

Automated systems:

Automated Fibre (Placement) (AFP), Automated Tape Laying (ATL), preforms, 3D weaving, filament winding. Benefits, associated costs, current applications. For example, Industry 4.0 impact on organisations, including the integration of automation, robots, PLCs, digital systems and manufacturing engineering systems. Use of tools and techniques associated with lean manufacturing and process improvement such as seven wastes, continuous flow, Kanban (pull System), just-in-time (JIT), lean simulation activities, value stream mapping, Poke Yoke.

Liquid resin processes:

Resin Transfer Moulding (RTM), Resin Film Infusion (RFI), SPRINT (Trade name surface coating), Relative Temperature Index (RTI), Liquid Resin Infusion (LRI), Vacuum Assisted Resin Transfer Moulding (VARTM)

Manufacturing methods and their applications, such as machining, joining, forming, assembling, shaping, processing, printing, moulding, extruding and casting; use of production methods e.g. single, batch, flow, mass

Advantages and disadvantages of traditional and modern composite manufacturing techniques, tool design, material selection, flow media

Adhesion and surface treatments:

Different types of adhesives for composite structures; adhesion procedures and adhesive testing

Surface preparation treatments for bonding composite surfaces e.g., grit blasting, sanding and solvent degrease.

Quality assurance for aerospace composite production processes:

Quality assurance and management systems; compliance including ISO9001, AS9100, ISO 14001 and TS16949.

LO3 **Correlate defects, their identification and evaluation**

Failure modes:

Introduction to different failure modes and mechanisms in composite materials and structures.

Defects:

Manufacturing and in-service defects may occur in a composite component Identify the causes of these defects and their implications. Barely Visible Impact Damage (BVID), impact, compression after impact, ballistic, birdstrike, lightning strike.

Evaluation of defects:

What analysis and testing is carried out at OEM to define acceptable defects?

Use of problem-solving tools/techniques such as practical problem solving (PPS), root cause analysis (RCA) and process failure mode effects analysis (PFMEA).

Testing methods:

Testing methods available for checking for defects: visual, acoustic, shearography, thermography, ultrasonic and X-ray

Testing methods to check quality such as non-destructive and destructive methods; measurement of variables such as dimensions, weight, signal, temperature, time

Analysing and interpreting data/information for documentation such as Parts Per Million (PPM) quality adherence, cost analysis and test data.

LO4 **Review repair methods and techniques stated in Structural Repair Manuals (SRM) or Aircraft Repair Manual (ARM) from the Design Authority (DA)**

Bonding:

Mechanical and chemical surface preparation, bond joint types, mechanical joints, bonding composites and metals, adhesive selection, mechanical testing of joints.

Repair:

Common repair techniques, allowable repairs, calculating repair limits, scarf repairs, stepped repairs, core repairs; Repair requirements: dependence on structural classification primary, secondary and tertiary and criticality of repair, restoration of structural capability, ability to withstand design loads, maintenance of aerodynamic shape, restoration of thermal and electrical properties; minimisation of downtime, repair materials and weight gain.

Structural integrity:

How repairs affect structural integrity, what additional checks are required, repair design calculations for patch repairs including the load carrying capacity of the joint and the adherend, joint and overlap lengths and peel stress.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Distinguish between the different constituents of composite materials used in aerospace engineering		
P1 Describe the function of the fibre and subsequent reinforcement in a composite material and numerically describe its contribution to laminate strength, and how this is changed with post-curing. **P2** Distinguish matrices used in aerospace engineering, including thermoset, thermoplastic, metal, and ceramic, with their benefits and typical applications.	**M1** Summarise the benefits of different core materials and numerically show the benefits of sandwich panels.	**D1** Explain how coatings and surface materials are used to protect composite structures from environmental factors, including lightning strike.
LO2 Compare key manufacturing processes used in aerospace composite production		
P3 Describe why balanced and symmetrical laminates are important in composite design and explain where an unbalanced layup may be beneficial. **P4** Compare the various types of tooling materials used in aeronautical composite manufacture and highlight a tooling feature specific to each manufacturing method.	**M2** Compare the applications, benefits, limitations, and associated cost of any three automated manufacturing methods.	**D2** Appraise how liquid resin systems are being introduced into aerospace composite manufacture and discuss their advantages and disadvantages.

Pass	Merit	Distinction
LO3 Correlate defects, their identification and evaluation		
P5 Correlate manufacturing and in-service defects and attribute a possible effect of the defects. **P6** Explain BVID and how this would present itself in both a solid composite structure and a sandwich panel.	**M3** Describe the testing carried out at OEM/DA to define allowable defect limits on flight critical components.	**D3** Compare six NDT methods, describing their advantages, disadvantages, applications and associated costs.
LO4 Review repair methods and techniques stated in Structural Repair Manuals (SRM) or Aircraft Repair Manual (ARM) from the Design Authority (DA)		
P7 Describe both the mechanical and chemical preparation required for bonding of metallic and composite parts. **P8** Using a structural repair manual, review the different allowable repair types and their restrictions.	**M4** Mechanically compare bonded and bolted composite joints and explain the benefits of four different bonded joint designs.	**D4** Explain how repairs affect the structural integrity of a flight component and what testing should be carried out at OEM/DA to allow that repair to be carried out.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Advani S.G. and Hsia, K.T. (Editors) (2012). Manufacturing techniques for polymer matrix composites (PMCs). Elsevier.

Carrera E. (2016) *Composite Materials and Structures in Aerospace Engineering*. Trans Tech Publications.

Dorworth L. C., Gardiner G. L., and mellema G. M. (2009) *Essentials of Advanced Composite Fabrication & Repair,* Aviation Supplies and Academics, Inc.

Giurgiutiu V. (2022) Stress, *Vibration, and Wave Analysis in Aerospace Composites – SHM and NDE Applications*. 1st Ed. Elsevier.

Guha P. (2022) *Composites Innovation: Perspectives on Advancing the Industry*. 1st Ed. CRC Press.

Hull D. and Clyne T. W. (2019) *An Introduction to Composite Materials*. 3rd Ed. Cambridge: Cambridge University Press.

Jawaid M. and Thariq M. (Editors) (2018) *Sustainable Composites for Aerospace Applications*. 1st Ed. Elsevier.

Jones R. M. (2018) *Mechanics of Composite Materials*. 2nd Ed. CRC press.

Matthews F. L. and Rawlings R. D. (1999) *Composite Materials: Engineering and Science.* Cambridge: Woodhead Publishing.

Sultan M.T.H., Rajesh M. and Jayakrishna K. (2022) *Repair of Advanced Composites for Aerospace Applications.* 1st Ed. CRC Press.

Nezhad H.Y. and Thakur V.K. (2022) *Composites Assembly for High Performance Fastener-less Structures*. London: Institution of Engineering and Technology.

Vassilopoulos A.P. (2019) *Fatigue Life Prediction of Composites and Composite Structures*. 2nd Ed. Elsevier.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Aerospace

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

International Journal of Aerospace Engineering

Journal of Aircraft

Journal of Aerospace Engineering

Journal of Aerospace Information Systems

Journal of Propulsion and Power

SAE International Journal of Aerospace

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 5031: Advanced Composite Materials for Aerospace Applications

Unit 4045: Turbine Rotary Wing Mechanical and Flight Systems

Unit Code: D/651/0781

Level: 4

Credits: 15

Introduction

Leonardo da Vinci produced the first conceptual helicopter design in 1493. However, due to a lack of technological knowledge, helicopter production did not occur until the 1940s. These technologically complex machines require engineers to utilise skills from both mechanical and electrical engineering disciplines in order to ensure they function safely in all environments.

This unit explores the roles of individual mechanical and electrical rotary wing flight systems and explains their interrelationships in modern integrated flight controls. Finally, students will be exposed to the need for Health and Usage Monitoring Systems (HUMS) and systems methods to overcome airframe fatigue failure.

On successful completion of this unit students will be able to show knowledge, skills and behaviours relating to mechanical airframe control systems associated with rotary wing flight, interconnections between different flight systems in modern integrated flight controls, function/operation of rotary wing transmission systems and the efficiency of transmission system components, requirements and system operation of typical rotary wing hydraulic systems, designing a hydraulic system solution(s) for a given application, and need for Health Usage Monitoring Systems and the methods used to combat airframe fatigue failure.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the mechanical airframe control systems associated with rotary wing flight, explaining the interrelationships between flight systems in modern integrated flight controls

LO2 Determine the operation of rotary wing transmission systems and the efficiency of transmission system components

LO3 Analyse the requirements and system operation of typical rotary wing hydraulic systems and design a hydraulic system to solve a given application

LO4 Justify the need for Health and Usage Monitoring Systems (HUMS) and the methods used to combat airframe fatigue failure.

Essential Content

LO1 **Describe the mechanical airframe control systems associated with rotary wing flight, explaining the interrelationships between flight systems in modern integrated flight controls**

Cyclic control:

Collective control, swashplate, yaw control: anti-torque control, tail rotor, bleed air, No Tail Rotar (NOTAR).

Main rotor head:

Design and operation features, blade dampers: function and construction, rotor blades.

Main and tail rotor blade:

Construction and attachment; trim control, fixed and adjustable stabilisers.

System operation:

Manual, hydraulic, electrical and fly-by-wire, artificial feel, Integrated Modular Avionics, auto flight.

LO2 **Determine the operation of rotary wing transmission systems and the efficiency of transmission system components**

Gearboxes and clutches:

Main and tail rotors, clutches, free wheel units and rotor brake.

Tail rotor drive shafts:

Flexible couplings, bearings, vibration dampers and bearing hangers

Gearbox and transmission system calculations.

LO3 **Analyse the requirements and system operation of typical rotary wing hydraulic systems and design a hydraulic system to solve a given application**

System layout:

Schematic diagrams, BS ISO 1219-1:2012+A1:2016 circuit symbols.

Hydraulic fluids:

Hydraulic reservoirs and accumulators

Pressure generation: electric, mechanical, pneumatic. Emergency pressure generation, filters, pressure control, power distribution, indication and warning systems, interface with other systems.

LO4 **Justify the need for Health and Usage Monitoring Systems (HUMS) and the methods used to combat airframe fatigue failure**

HUMS components and architecture

Basic components in HUMS (including various sensors and data management), HUMS indicators for measurement and recording for various components of rotary wing aircraft.

HUM: vibration:

Sources and effects, balancing and rigging, vibration monitoring, Active Vibration Reduction, condition-based maintenance and its impact on operating costs.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the mechanical airframe control systems associated with rotary wing flight, explaining the interrelationships between flight systems in modern integrated flight controls		
P1 Describe the function and characteristics of the mechanical flight controls fitted to rotary wing aircraft. **P2** Examine different types of operating systems that can be utilised to operate the mechanical flight control systems.	**M1** Discuss the mechanical and electrical functions of a rotary wing auto flight system.	**D1** Analyse how integrated modular avionics systems receive inputs from, and provide outputs to, mechanical and auto flight control systems, including the need for redundancy.
LO2 Determine the operation of rotary wing transmission systems and the efficiency of transmission system components		
P3 Determine the layout, component function and operation of the transmission systems fitted to a turbine-powered helicopter. **P4** Explain the principles of operation of both NOTAR and Fenestron tail rotors.	**M2** Illustrate, with the aid of diagrams, the operation of clutches and free wheel units, in all modes, in a typical rotary wing aircraft powered by at least two turbine engines.	**D2** Using given test data, show the mechanical parameters of a typical main rotor epicyclic gearbox.

Pass	Merit	Distinction
LO3 Analyse the requirements and system operation of typical rotary wing hydraulic systems and design a hydraulic system to solve a given application		
P5 Using standard hydraulic symbols, design a helicopter hydraulic schematic that incorporates at least two independent hydraulic systems. **P6** Analyse the operation of a typical hydraulic system in normal operation.	**M3** Explain how rotary wing hydraulic systems interface with other aircraft systems, such as autopilot.	**D3** Evaluate the effects of a single hydraulic system failure on dual hydraulic helicopter systems.
LO4 Justify the need for Health and Usage Monitoring Systems (HUMS) and the methods used to combat airframe fatigue failure		
P7 Describe the sources of vibration and its effects on a helicopter. **P8** Justify the techniques used by engineers to adjust flying controls and rotors for optimal performance.	**M4** Analyse the reasons why Health Usage Monitoring is an integral part of modern helicopter operations and how it is used to combat fatigue failure.	**D4** Evaluate the practical solutions helicopter manufacturers offer to combat vibration at the source.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird J. and Ross C. (2012) Mechanical Engineering Principles. 2nd Ed. New York: Routledge

Coyle S. (2009) *Cyclic and Collective.* Lebanon: Eagle Eye Solutions.

Moir I. and Seabridge A. (2008) *Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration*. 3rd Ed. Wiley.

Giampaolo T. (2020) *Gas Turbine Handbook – Principles and Practice*. 5th Ed. River Publishers.

Lau S., Brisbois F., Gregoire J., Hasty T., Alamond J., Antolick L. and Green D. (2013) *Health and Usage Monitoring Systems Toolkit.* Washington DC: International Helicopter Safety Team.

Sadraey M.H. (2013) *Aircraft design: A Systems Engineering Approach.* Chichester: Wiley.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Aerospace Science and Technology

Electrical Power Systems Research

Green Energy and Intelligent Transportation

International Journal of Turbo and Jet Engines

Journal of Aircraft: Wing Design by Numerical Optimization

The Electricity Journal

Link

This unit links to the following related unit:

Unit 5032: Advanced Turbine Rotary Wing Aircraft Mechanical and Flight Systems.

Unit 4046: Fundamentals of Nuclear Power Engineering

Unit Code: **K/615/1539**

Level: **4**

Credits: **15**

Introduction

Nuclear power generates about 11% of global electricity production and this figure is expected to increase significantly over the next 30 years. Many countries now see nuclear power as the most effective way of generating low-carbon, affordable and sustainable electricity capacity. In the UK, nuclear power generates about 20% of current electricity. However, as old nuclear and fossil plants are retired, the government is supporting the development of new nuclear power stations across the UK. Each station will employ up to 1000 workers directly, most of whom will require higher-level engineering and technical skills.

The success, or otherwise, of the UK's nuclear power programme will rely on the development of a professional workforce with the knowledge and skills required to drive improvements in the design and operation of the plants that improve safety, increase efficiency, reduce environmental impacts and deal effectively with radioactive wastes.

This unit introduces students to the fundamentals of nuclear reactor engineering and related issues. The unit explains how heat generated from nuclear fission is initiated, controlled and extracted from a nuclear reactor; how the heat is used to generate steam; and how the steam drives a turbo-generator to produce electricity. The safety issues, radiological hazards and environmental impacts associated with nuclear power generation, the nuclear fuel cycle and the associated radioactive wastes are described in a rational and balanced manner.

Topics in this units include: nuclear science fundamentals; the fission process; the fission chain reaction; nuclear reactor design fundamentals; the evolution of reactor designs in the UK; nuclear thermal hydraulics and heat transfer processes; steam production and turbine operation; and electricity generation. Nuclear safety is the common thread running through the unit; specifically, the unit explains how technology is used to eliminate or reduce the risks of accidents. The unit also provides an overview of the UK nuclear industry, the nuclear fuel cycle, decommissioning and radioactive waste management. Case studies are included to examine the root causes and lessons learned from previous reactor accidents.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the development, current status and future outlook for the nuclear industry in the UK

LO2 Apply science and engineering principles to explain the design and operating principles of a nuclear power reactor

LO3 Compare and contrast different reactor designs, weighing the advantages and disadvantages of each

LO4 Identify the safety concerns associated with nuclear power and explain how risks are controlled, eliminated or mitigated in the design and operation of a modern nuclear reactor plant.

Essential Content

LO1 Describe the development, current status and future outlook for the nuclear industry in the UK

Historical perspectives:

Discovery and explanation of fission; implications for energy generation and weapons application; discovery of plutonium; significance for nuclear weapons; Chicago Pile #1; Manhattan Project during WW2; The UK's Reactor Development Programme: Windscale Piles; Magnox Reactor Programme; Advanced Gas Reactor (AGR) Programme; Pressurised Water Reactor Programme; Current status of nuclear power generation in the UK.

The UK nuclear industry:

Key stakeholders; nuclear fuel cycle activities: uranium purification, conversion and fuel manufacture at Springfields; uranium enrichment at Capenhurst; spent fuel reprocessing at Sellafield; status of nuclear power plant decommissioning; radioactive waste management and disposal; UK Nuclear Regulatory Framework (safety, security, safeguards and environmental protection).

LO2 Apply science and engineering principles to explain the design and operating principles of a nuclear power reactor

Nuclear fundamentals:

Nuclear reactions; the fission reaction; products of fission (heat, fission fragments, neutrons, gamma rays); quantity and form of energy release in fission compared with fossil fuels; the fission chain reaction; fissile vs fissionable isotopes; the need for neutron moderation; neutron cycle in a moderated (thermal) reactor; neutron leakage, absorption and reproduction; multiplication factor (three-factor formula); critical, sub-critical and supercritical configurations; conversion and breeding reactions.

Nuclear reactor principles (core design):

Nuclear fuel: Purpose and requirements; physical and chemical forms (metal, oxide, others); fuel geometry; practical fuel types

Fuel cladding: Purpose and requirements; physical and chemical forms; cladding geometry; practical cladding types

Moderator: Purpose and requirements; practical moderators; moderator effectiveness; advantages and disadvantages of water, heavy water and graphite as moderators

Coolant: Purpose and requirements; practical coolants; coolant selection; advantages and disadvantages of water as a reactor coolant

Control materials: Purpose and requirements; strong neutron absorbers; practical control absorbers; control rods/plates; liquid neutron absorbers (boric acid).

Nuclear reactor principles (plant design):

Core heat removal processes: heat transfer from fuel pins to coolant; role of conduction, convection; power generation and thermal limits; coolant temperature rise versus power and coolant flow rate

Steam generation: heat exchanger/boiler design and operational features; design and operation of steam turbines, condensers, thermal efficiency of steam cycle

Electricity generation: design and operating principles of turbo-generator; arrangements for connection to grid and transmission

Ancillary systems: coolant treatments; HVAC; containment; emergency systems.

Aspects of nuclear reactor operation:

Achieving criticality; controlling reactivity; power operation; thermal feedback; self-regulation and load following characteristics; fuel depletion effects; response to reactor SCRAM; decay heat removal.

LO3 **Compare and contrast different reactor designs, weighing the advantages and disadvantages of each**

Current reactor types:

Key performance indicators: capacity; load factor; availability; efficiency; safety; environmental impact; cost. Design, operation and advantages and disadvantages of different reactor types: MAGNOX, AGR, PWR, BWR, Candu, LMFBRs; thermal versus fast reactors and uranium utilisation.

Future reactor types:

Generation IV reactors – design goals; high-temperature gas reactors; liquid metal cooled fast reactors, supercritical water reactors, molten salt reactors; small modular reactors (SMRs).

LO4 **Identify the safety concerns associated with nuclear power and explain how risks are controlled, eliminated or mitigated in the design and operation of a modern nuclear reactor plant.**

Radiation protection in nuclear reactors:

Types, properties of ionising radiations; radiation units (Bq, Sv); health effects of radiation exposure; regulations and dose limits; radiation protection practices

Sources of radiation (reactor operating, reactor shut-down, spent fuel, others); direct radiation and analysis of radiation shielding; neutron activation processes (water, impurities, crud) – mitigation measures; contamination control arrangements

Nuclear incidents and accidents: types of reactor accident; prevention, protection and consequence mitigation systems (including containment); radiological consequences (on-site and off-site); on- and off-site emergency response arrangements.

Reactor accident case studies:

Windscale (1957); Three Mile Island (1979); Chernobyl (1986); Fukushima (2009): Root causes, lessons learned.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the development, current status and future outlook for the nuclear industry in the UK		
P1 Construct a timeline highlighting the key milestones in the development of nuclear power reactors. **P2** Describe the essential design features of Magnox, AGR and PWR reactors.	**M1** Explain the significance of each milestone in the development of nuclear power. **M2** Explain the rationale for the design evolution of UK nuclear reactors.	**D1** Compare and contrast the evolution of reactor design in the UK with approaches taken in other countries and critically examine the key decisions and their impact on the programme.
LO2 Apply science and engineering principles to explain the design and operating principles of a nuclear power reactor		
P3 Using scientific and engineering principles, explain the essential steps involved in the conversion of energy released in the fission process to electricity. **P4** Identify the key components of a nuclear power reactor and explain their purpose.	**M3** Undertake calculations to estimate reactivity, thermal power generation and fuel utilisation in a nuclear reactor of specified dimensions and composition. **M4** Illustrate the underlying rationale for materials selection for key components of a nuclear power reactor.	**D2** Critically examine the key design features which place limitations on electrical power generation from a nuclear reactor and suggest solutions to overcome these limitations.

Pass	Merit	Distinction
LO3 Compare and contrast different reactor designs, weighing the advantages and disadvantages of each		
P5 Compare key performance indicators (KPIs) for modern nuclear power reactors. **P6** Measure the various reactor types used throughout the world against the KPIs set out in P5.	**M5** Explain the rationale underlying KPIs for modern nuclear power reactors. **M6** Critically evaluate the advantages and disadvantages of different reactor types for different applications.	**D3** Critically evaluate the concepts being considered for future Generation IV nuclear power reactors, measuring each concept against specific Gen IV design goals.
LO4 Identify the safety concerns associated with nuclear power and explain how risks are controlled, eliminated or mitigated in the design and operation of a modern nuclear reactor plant.		
P7 Describe the main sources and types of ionising radiation in an operating reactor and explain how these are controlled. **P8** Describe the most likely causes and potential consequences of a nuclear reactor accident.	**M7** Undertake calculations to evaluate the effectiveness of radiation protection measures in a nuclear reactor. **M8** Illustrate the key safety systems designed to reduce the likelihood of reactor accidents or mitigate the consequences.	**D4** Evaluate the root causes of three well-documented reactor accidents (case studies) and formulate recommendations for improvements in design and/or operational management.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Hore-Lacy, L. (2012) *Nuclear Energy in the 21st Century: World Nuclear University Primer*. 3rd Ed. London: World Nuclear University Press.

Kenneth D. K. (2017) *Nuclear engineering handbook.* 2nd Ed. CRC Press.

Knief, R. A. (1992) *Nuclear Engineering*. Carlsbad: Hemisphere.

Lamarsh, J. R. and Baratta, A. J. (2014) *Introduction to Nuclear Engineering.* 3rd Ed. India: Pearson.

Lewis B.J., Onder E.N. and Prudil A.A. (2017) *Fundamentals of Nuclear Engineering.* Wiley.

Websites

http://www.world-nuclear.org/	World Nuclear Association (General reference)
https://www.niauk.org/	Nuclear industry Association (General reference)

Links

This unit links to the following related units:

Unit 5033: Nuclear Reactor Operations

Unit 5040: Nuclear Safety Case Development.

Unit 4047: Railway Operations

Unit Code: J/617/3662

Level: 4

Credits: 15

Introduction

Railway Operations is responsible for managing the operations and maintenance of rail systems, subsystems, assets and services to ensure that they function in an effective, safe and synchronised way. Rail Engineers and technicians are critical to operations and are required to understand how these elements function, interface and interact to prevent failures and optimise overall rail operations. It involves systems and assets such as signalling, electrification, telecommunications, traction & rolling stock, stations, command & control, tracks and many others.

This unit focuses on how the railway works as a system and the role that advanced rail technicians have within it. Identifying critical functions and interfaces across the railway system and how to manage their operation and maintenance. Discussing the importance of 3rd party and internal business requirements and operational interfaces; the need for and understanding of client confidentiality and compliance with corporate policies including ethics, equality and diversity and sustainability; and how the railway works commercially including contractual principles and financial systems, forecasts and budgets, and performance implications and performance management techniques.

The unit explores how the railway is evolving. Taking into consideration the awareness and understanding of new technological developments across the Railway and how these will impact its future operation.

Students who have completed this unit as part of their HNC studies will be well placed to apply for employment as Advanced Rail Technicians or other similar roles within the railway industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain how the railway works as a system

LO2 Explore the role that rail technicians have in railway operations

LO3 Explain the commercial operations of a railway

LO4 Explore the ways in which the railway is evolving.

Essential Content

LO1 **Explain how the railway works as a system**

The railway system:

The various systems, subsystems and assets that form a railway system

The principle function and significance of each system and asset to rail operation

How the systems and assets interact together to operate a railway.

The interfaces across a railway system:

The different interfaces between the systems of a railway

The requirements, conditions and tolerances of the different types of interfaces

The criticality levels of the system interfaces and impacts of failures on the operation of a railway

The monitoring and response systems developed to reduce the risk of system and interface failures.

LO2 **Explore the role that rail technicians have in railway operations**

Management of the operations and maintenance of a railway system:

Understand the relationship between operations management and the maintenance system and how they impact the performance of the railway system

Identify and distinguish between systems and assets that function within solely operations management, solely maintenance or a combination of both responsibilities

Importance of adhering to maintenance schedules and using optimisation activities to increase railway operation reliability and reduce the rate of system and asset failures

The analytical approach to monitoring the performance of all railway systems, understanding the major risk factors, real time detection of unexpected changes and problem-solving approach to issues

System and asset maintenance activities such as engineering walkdowns, inspections & testing, categorising findings & defects and reporting issues

Conduct and supervise railway system repairs

Comply with required Quality Assurance and Health & Safety regulations and procedures when performing operations and maintenance activities

Keeping operations and maintenance records updated.

Understand the impacts business requirements, security, client confidentiality and compliance with corporate policies have on railway operations:

Differentiate between the conditions, requirements and approach taken when facing 3rd party businesses as opposed to internal businesses

Adhere to privacy, data protection, security and corporate policies and regulations.

LO3 **Explain the commercial operations of a railway**

Focus of commercial operations:

Markets and customers

Freight services.

Commercial railway departments:

Financial systems, forecasting and budgeting

Planning and timetabling

Contracts and contractual principles

Sales and marketing.

Performance Management:

Performance implications

Performance management techniques.

LO4 **Explore the ways in which the railway is evolving.**

Current concerns that the future railway systems will have to address:

Growing passenger and freight demands

Costs of construction, maintenance and operation

Energy efficiency, carbon footprint and environmental protection

Rising expectations and adaptation of customers.

Current and future technological developments in the railway:

High-speed and hyper-speed rail

Ergonomic station design

Big data and real time signalling

Passenger entertainment and interactive services

High speed internet using 5G.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain how the railway works as a system		
P1 Describe the various system and assets used on the railway, their interfaces and functions. **P2** Discuss how the various assets within a railway work together as a system.	**M1** Investigate the impacts and complications that different system interfaces can have on the overall railway performance.	**D1** Illustrate through the use of examples how the railway system performance is impacted by human behaviour and is a key factor of unreliability.
LO2 Explore the role that rail technicians have in railway operations		
P3 Illustrate how the operations management and maintenance systems relate to each other regarding the overall operation of a railway. **P4** Explore the role of rail technicians in the maintenance and optimization of railway operations. **P5** Examine the impacts business requirements, security, client confidentiality and compliance with corporate policies have on railway operations.	**M2** Assess the impact that poor adherence to the maintenance schedule can have on the overall reliability and performance of railway operations.	**D2** Evaluate how Quality Assurance regulations and conditions can differ between work carried out by 3rd party businesses and internal businesses.

Pass	Merit	Distinction
LO3 Explain the commercial operations of a railway		
P6 Describe the focus and scope of railway commercial operations. **P7** Discuss the importance of planning and monitoring of the commercial performance of the railway.	**M3** Examine the functions of the various commercial railway departments and the importance of monitoring and managing commercial performance.	**D3** Justify why it is important to monitor and manage the commercial performance of the railway and what the implications may be if it is not managed well.
LO4 Explore the ways in which the railway is evolving.		
P8 Identify the current concerns that future railway systems will have to address. **P9** Discuss what technological developments are being made to address current social and economical rail operations concerns and how they are evolving.	**M4** Analyse the major technological advancements and socio-economic factors that likely effect the evolution of the railway in the future.	**D4** Justify how higher passenger numbers and customer expectations drive the adoption of new technological developments in railways.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Pyrgidis, C.N. (2018). *Railway Transportation Systems: Design, Construction and Operation*. London: CRC Press.

Websites

uic.org	International Union of Railways (General reference)
http://www.theiet.org	The IET Railway Network Railway (General reference)
http://www.railway-technical.com	Railway Technical (General reference)
http://www.imeche.org/	IMechE Railway Railway (General reference)

Links

This unit links to the following related units:

Unit 4012: Engineering Management

Unit 4017: Quality and Process Improvement

Unit 4048: Track Design

Unit 4050: Principles of Electrification

Unit 4052: Railway Telecommunications

Unit 4053: Traction and Rolling Stock Systems

Unit 4054: Passenger Safety and Security

Unit 4055: Management and Operations

Unit 4070: Command and Control Systems

Unit 4071: Introduction to Signalling Systems.

Unit 4048: Track Design

Unit Code: L/617/3663

Level: 4

Credits: 15

Introduction

The systems that enable a railway to function in an optimum way fall under the area of Command, Control and Communication (CCC). Such railways operate in a safe and timely fashion, and without any delays or cancellations. CCC specialists operate and maintain these systems to ensure the trains operate as planned thus ensuring the passengers enjoy a great service.

This unit focuses on the various systems and subsystems that make up the CCC. Initially, it establishes what CCC is, its purpose and principle of operation. It then goes on to discuss design considerations, such as how health and safety may be embedded into the system, aspects of protection, considers risk and failure modes as well as ergonomic and human factors, IT systems, telecommunications, cybersecurity, and operational and maintenance aspects for the CCC system. The unit then focuses on the Common Safety Method for Risk Evaluation and Assessment (CSM RA), and the European Rail Traffic Management System (ERTMS) and its subsystems: Global System for Mobile Communications – Railway (GSM-R), European Train Control System (ETCS) and European Train Management Layer (ETML).

Students who have completed this unit as part of their HNC studies will be very well placed to apply for employment as Command, Control and Communications (CCC) Advanced Technicians or other similar roles within the railway industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the function of the Control, Command and Communication (CCC) system and the role it plays in the operation of a railway

LO2 Explore CCC design factors and operational considerations

LO3 Explain the Common Safety Method (CSM)

LO4 Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).

Essential Content

LO1 Explain the function of the Control, Command and Communication (CCC) system and the role it plays in the operation of a railway

The Control, Command and Communication (CCC) system:

Determining what the CCC system is

The CCC system function and principle of operation

The function and principle of operation of each CCC subsystem.

Legacy, modern and future rail signalling and train control systems:

Similarities and differences between the various systems.

LO2 Explore CCC design factors and operational considerations

Design factors:

Embedding health and safety into the CCC system

Building protection into the design

Risk and failure modes

Ergonomic and human factors

IT systems − architecture, hardware and software

Security technology − cybersecurity considerations, precautions and levels of access

Telecommunications systems.

Operational considerations:

Operational and maintenance requirements

Demonstrating that operational and maintenance requirements are successfully met.

The commissioning certification process:

Designing, implementing and operating a CCC system.

Purpose and processes management:

For data, configuration and change.

LO3 **Explain the Common Safety Method (CSM)**

The need for CSM:

Safety requirements in a competitive environment

Risk evaluation and assessment

Processes harmonisation for risk evaluation and assessment.

Risk management process of CSM RA:

The framework of the risk management process

Analysis and evaluation of hazards

Producing suitable and sufficient risk assessment for a change

Proposing a technical, operational or organisational change.

LO4 **Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).**

The European Rail Traffic Management System (ERTMS):

The ERTMS system of standards

Purpose, targets and developments

ERTMS function and operation

Implementation and deployment strategies.

The Global System for Mobile Communications – Railway (GSM-R):

Communicating between train and trackside

The GSM-R principle of operation

GSM-R capabilities and limitations

Subsequent communication evolutions.

The European Train Control System (ETCS):

The need for ETCS and its importance to safety

ETCS principle of operation

ETCS numbering levels

Implementation and deployment.

The European Train Management Layer (ETML):

Intelligently optimising train movements

ETML principle of operation and functional structure.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the function of the Control, Command and Communication (CCC) System and the role it plays in the operation of a railway		
P1 Describe the function of the CCC system as used in the railway. **P2** Explain the principle of operation of the CCC system.	**M1** Explore the principle of operation of the various CCC subsystems.	**D1** Explain how rail signalling and train control systems evolved.
LO2 Explore CCC design factors and operational considerations		
P3 Explain the need to embed health and safety aspects in a CCC system during the design phase. **P4** Explain why protection must be built in a CCC system during the design phase.	**M2** Discuss operational and maintenance requirements in railway CCC systems and explain how they can be successfully met.	**D2** Justify the importance of incorporating cybersecurity in a CCC system and highlight how the system could be compromised if it gets cyberattacked.
LO3 Explain the Common Safety Method (CSM)		
P5 Explain why safety requirements were considered a barrier to open competition across EU railways. **P6** Explain how CSM RA enables processes harmonisation for risk evaluation and assessment.	**M3** Analyse the framework of the CSM RA risk management process explaining three risk acceptance principles.	**D3** Investigate, with the use of examples, how the CSM RA could be put to use when a technical, operational or organisational change is proposed.
LO4 Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).		
P7 Describe the problem that the ERTMS was developed to solve. **P8** Explain the technical targets of ERTMS.	**M4** Evaluate each ETCS and interpret its various numbering levels using a comparative table.	**D4** Evaluate ERTMS implementation strategies focusing on the main factors that compromised deployment efforts.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Hall, C. (2016) *Modern Signalling Handbook*. 5th ed. Shepperton: Ian Allan Publishing.

Yu, F.R. (2018) *Advances in Communications-Based Train Control Systems*. London: CRC Press.

Websites

orr.gov.uk	Office of Rail Regulation Common Safety Method for Risk Evaluation and Assessment (Guidance)
uic.org	Worldwide Railway Organisation RTMS (Article)
irse.org	Institute of Railway Signal Engineers Technology Updates (General reference)
ertms.net	ERTMS ERTMS Updates (General reference)

Links

This unit links to the following related units:

Unit 4016: Instrumentation and Control Systems

Unit 4047: Railway Operations

Unit 4052: Railway Telecommunications

Unit 4055: Management and Operations

Unit 4057: Networking

Unit 4059: Computer Systems Architecture

Unit 4071: Introduction to Signalling Systems.

Unit 4049: Principles of Overhead Power

Unit Code: Y/617/3665

Level: 4

Credits: 15

Introduction

Overhead Line Equipment (OLE) infrastructure is dependent on sound electrical knowledge and ability to follow set procedures declared by authorised Railway Regulatory documentation. This unit is for delegates undertaking Overhead Line Equipment operation and maintenance paths.

The aim of this unit is to build the knowledge and skills, with emphasis on AC and DC technology, used within OLE. Principles are used to build a foundation for engineering knowledge and follow on to safety procedures used in high voltage systems. Students would be expected to take on electrical infrastructure work determined by Electrification Engineers working on specific projects to prove and verify engineering equipment.

The importance of test results depends on data accuracy and correct analytical methods used by project engineers to verify engineering operations in order to manage technical issues raised. The unit also covers the application of electrical principles with instrumentation skills to verify acceptable equipment operation and the continuous supply for railway electrification use.

On successful completion of this unit students will be able to apply the mathematical and engineering skills required to analyse AC signal output from the power supply, identify where a structure failure occurs and find possible solutions while working alongside electrical engineers in a safe manner. Students who have completed this unit as part of their HNC studies will be well placed to apply for employment as an OLE Design Engineer or other similar roles within the rail industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the key characteristics of a magnetic field in electrical power use

LO2 Explain the operation of a capacitor in an AC circuit including, circuit currents and voltages obtained using practical skills

LO3 Describe the types and function of capacitors in AC and DC circuits, clearly comparing their uses and differences

LO4 Determine the sum and difference of two sinusoidal signals with mathematical expressions with different phases.

Essential Content

LO1 Describe the key characteristics of a magnetic field in electrical power use

Principles of Electromagnetic Induction:

Faraday's and Lenz's laws

Properties of magnetism applied to a coil

EMF, potential difference and current in a coil using high voltages (HV).

Principles of generators and motors:

Fleming's right- and left-hand rules

Creation of AC waveforms from a generator

Difference in design and use of AC and DC motors

Transformer Theory for single-, dual- and three-phase supplies

Inductor and Resistive (LR) circuits and impedance (Z).

LO2 Explain the operation of a capacitor in an AC circuit, including circuit currents and voltages obtained using practical skills

Key design and construction features and components of capacitors for AC and DC systems:

Types of capacitors (applicable to AC and DC systems)

Construction of a capacitor (polarised and non-polarised)

Charge on a capacitor and hazards in HV uses

Energy stored in a capacitor (AC and DC type of circuits)

Capacitors in series and parallel configuration applications

Comprehension of the difference between actual and calculated total capacitance

Railway applications for multiple capacitors used for rectification.

LO3 **Describe the types and function of capacitors in AC and DC circuits, clearly comparing their uses and differences**

Difference in design calculations and components for AC and DC capacitors:

Charging and discharging of a capacitor in AC circuits and DC circuits Charging and discharging times using exponential equations to determine waiting times.

DC Transients and RC circuits and Impedance on circuits

Phase difference and phasor diagrams to determine output waveform types

Leading and lagging circuits to control delays in circuit uses.

LO4 **Determine the sum and difference of two sinusoidal signals with mathematical expressions with different phases.**

Complex numbers and resultants using mathematics

Adding two sine waves using oscilloscope for practical method

Adding two sine waves using graphical method

Adding two sine waves using vector method

Subtracting the sine waves that are out of phase

Leading and lagging circuit examples using LRC circuits

Impedance measurement and calculations used to verify it.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the key characteristics of a magnetic field in electrical power use		**D1** Evaluate the main factors of single-, dual- and three-phase AC cables for the operation of overhead power supply.
P1 Explain what a sinusoidal waveform is and why it is the preferred method of supplying electrical power. **P2** Determine the characteristics of a sinusoidal AC waveform using single phase AC circuit theory including cycle time, Root Mean Square (RMS), peak value and peak to peak values for current and voltages. **P3** Explain the relationship between a magnetic and electric field in the supply of electrical power through a single-phase AC cable.	**M1** Analyse the effects of a magnetic field between two HV single phase AC cables.	
LO2 Explain the operation of a capacitor in an AC circuit, including circuit currents and voltages obtained from a Live circuit		**D2** Critically evaluate the use of earthing cables for HV cable isolation and earthing uses.
P3 Explain the construction of a non-polarised capacitor in AC and polarised capacitor in DC application, configured in parallel for total capacitance value. **P4** Identify hazards associated with a charged capacitor in HV circuits.	**M2** Compare the total capacitance of multiple cables in series and parallel configurations. **M3** Discuss the stages required to safely measure the capacitance in HV circuits.	

Pass	Merit	Distinction
LO3 Describe the types and function of capacitors in AC and DC circuits, clearly comparing their uses and differences		
P5 Illustrate how charging and discharging of a capacitor can be determined using calculations. **P6** Explain the relationship between the voltage and current for a HV cable with inductive, capacitive and resistive (LRC) circuit.	**M4** Justify the use of earthing cables in High Voltage Alternating Current (HVAC) Circuits.	**D3** Investigate the effect of capacitance and inductance on a single phase HV XLPE power cable.
LO4 Determine the sum and difference of two sinusoidal signals with mathematical expressions with different phases.		
P7 Compare the results of adding and subtracting two in-phase, sinusoidal AC waveforms graphically. **P8** Draw the resultant of two out-of-phase AC circuits added and subtracted, using a phasor diagram method.	**M5** Create the resultant of two out of phase AC circuits using a spreadsheet and define the characteristics.	**D4** Analyse a complex resultant signal and identify the harmonic content present on it.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Barber, J. and Institution of Civil Engineers (2002) *Health & Safety in Construction: Guidance for Construction Professionals*. London: Thomas Telford.

Bird, J. (2004) *Electrical Circuit Theory and Technology*. London: Newnes.

IET. (2010) *Electrical Traction Systems*. London: The Institute of Engineering and Technology.

Websites

http://www.railway-technical.com	Railway Technical Electric Traction Power (Research)
http://www.networkrail.co.uk	Network Rail Apprenticeships – What You'll be doing? (General reference)
http://www.cablejoints.co.uk	Cable Joints 11Kv-33KV cables XLPE (Research)

Links

This unit links to the following related units:

Unit 4047: Railway Operations

Unit 4050: Principles of Electrification

Unit 4053: Traction and Rolling Stock Systems.

Unit 4050: Principles of Electrification

Unit Code: D/617/3666

Level: 4

Credits: 15

Introduction

Railway infrastructure depends on electrical knowledge and the ability to follow set procedures declared by authorised railway regulatory documentation and standards to suit high voltage environments. The requirements place significant emphasis on electrification technology, including both AC and DC configurations. This unit is fit for students undertaking electrical and plant maintenance, including operation of equipment on railway infrastructure assets.

The unit introduces students to electrical and electronics engineering skills, enabling them to collect and use electrical data from test results used by project engineers to manage technical problems and deal with any issues raised. Electrical principles applied with monitoring systems like SCADA for continuous supply of electricity to railway infrastructure equipment. This involves practical skills and procedures using HV switchgear it will allow the students to identify where and why a structure failure has occurred and find possible solutions through engineering groups.

On successful completion of this unit students pursuing this pathway would take on Electrical infrastructure work in both AC and DC regions, working alongside maintenance and electrical engineers. Students who have completed this unit as part of their Higher National Certificate studies will be well placed to apply for employment as an Electrification Technician or other similar roles within the rail industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe rail electrification and power distribution systems and technologies

LO2 Describe the various features and applications of electrical machines

LO3 Analyse the various ways of interfacing between rail electrification assets and equipment

LO4 Explain the principles required to undertake and direct installation, test commission, maintenance and renewal of railway electrification systems.

Essential Content

LO1 **Describe rail electrification and power distribution systems and technologies**

Application, function and operation of assets and equipment:

Electrical components: plugs, sockets, switches, lighting and fittings, junction boxes, relays, protection devices

Compressors: screw piston, rotary vane

Hydraulic motors: piston, gear, vane

Pipework, fittings and manifolds, and their application

Valves: poppet, spool, piston, disc and slide

Sensors and actuators: rotary, linear, mechanical, electrical

Pumps: positive, gear vane and piston.

Electrical hazards, legislation, regulations and standards related to working with electrical apparatus:

Including health and safety in all work practices and procedures

Identifying and managing hazards

Applying control measures to reduce the risk of harm to self

Describing aspects of legislation, regulations and standards.

Properties and behaviour of materials in the rail environment:

Mechanical, physical, thermal, electrical and magnetic.

High voltage and low voltage switchgear, transformers, rectifiers and protection:

Purpose, operation and application

Ensuring plant safety and the requirement to use specialist tools

Hazards associated with the installation and maintenance of switchgear

Component failure modes and causes.

High voltage and low voltage cabling and jointing:

Types of cables: multi-core cables, single-core cables, steel wire armoured (SWA), data cables, screened cables, fibre cables

Types of jointing techniques, their application and operation

Hazards associated with jointing techniques

Cable and joint failure modes and causes.

System appreciation of the following

The effects of short circuit and load flow on the performance of the system

The principles of how communication-electronic or associated systems function and interact e.g. SCADA

Knowledge of compressed air systems

Knowledge of power generation systems as used in the Railway industry

The principles of how Heating Ventilation Air Conditioning (HVAC) units/modules function.

LO2 **Describe the various features and applications of electrical machines**

Features, characteristics and application of alternating current (AC) machines:

AC motors

AC generators

Transformers.

Features, characteristics and applications of direct current (DC) machines:

DC motors

DC generators.

Operation of electrical machine control circuits and systems:

Stop/start/retain relay control circuits for AC or DC machines.

LO3 **Analyse the various ways of interfacing between rail electrification assets and equipment**

Physical and system interfaces of the electrifications systems and the wider rail network:

Overhead line

Electricity supplier DNO, electricity supplier

Switchgear AC and DC

Transformers

Rectifiers

Cabling HV and LV

SCADA

Traction and Rolling Systems

Signalling

Control and communications.

LO4 **Explain the principles required to undertake and direct installation, test commission, maintenance and renewal of railway electrification systems.**

Maintaining electrification systems from first principles:

Thermal imaging

Partial discharge

Trending

Condition monitoring

Harmonics

Power quality systems.

Using data analysis to improve the operation and maintenance of power equipment:

Cascading and truth tables

Logic/ladder diagrams

Sequential charts/tables

Functional diagrams.

Undertake and supervise:

Allocation and monitor of resources for electrification and plant engineering activities

Installation of electrification and plant assets

Maintenance on electrification and plant equipment and component

Establish the operational condition of electrification and plant assets

Undertake technical assessment of electrification and plant

Preventative and corrective maintenance of traction cabling systems and maintenance of traction cabling

Switching

Isolation and Earthing

Restoration of contact systems

Thermal imaging and partial discharge

Planning for testing

Transfer responsibility of electrification and plant equipment and components.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe rail electrification and power distribution systems and technologies		
P1 Identify the various design features, processes, equipment and systems used in rail electrification. **P2** Explain the function of systems and technologies used in power distribution on railways.	**M1** Explore the importance that legislation, regulations and standards have on avoiding electrical hazards.	**D1** Critically analyse the selection of cables for HV and LV distribution of power to the railway systems.
LO2 Describe the various features and applications of electrical machines		**LO2 and LO3**
P3 Explain the principle of operation of electrical machines. **P4** Differentiate between the AC and DC electrical machines.	**M2** Evaluate the principle operation of electrical machine control circuits and systems defining, where stop/start/retain relay control circuits are used.	**D2** Investigate the interfacing requirements between electrical machines and associated switchgear and differentiate between AC and DC systems.
LO3 Analyse the various ways of interfacing between rail electrification assets and equipment		
P5 Discuss how rail electrification assets and equipment interface. **P6** Differentiate between physical and system interfaces on the wider rail network.	**M3** Differentiate between current collection from 25KV AC system and from 750 DC system switchgear.	

Pass	Merit	Distinction
LO4 Explain the principles required to undertake and direct installation, test commission, maintenance and renewal of railway electrification systems.		
P7 Describe the principles of undertaking and directing the installation and commissioning of railway electrification systems. **P8** Describe the principles of undertaking and directing the maintenance and renewal of railway electrification systems.	**M4** Compare the various data analysis techniques used to improve the operation and maintenance of power equipment/	**D3** Compare the process of undertaking and supervising the installation of electrification assets and equipment to the scheduled renewal procedure.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Barber, J. (2002) *Health and Safety in Construction: Guidance for Construction Professionals*. London: Thomas Telford.

Bird, J. (2010) *Electrical Circuit Theory and Technology*. 4th ed. Oxford: Elsevier.

Websites

http://www.railway-technical.com	Railway Technical Electric traction power (Research)
http://www.theiet.org	The Institute of Engineering and Technology Railway electrification (Tutorials)
http://www.cablejoints.co.uk	Cable Joints 11kV Cable – Single Core XLPE Insulated AWA BS6622/BS7835 (Research)
http://www.siemens.com	Siemens Protection relays Tutorials applications and news (Tutorials)
http://www.toshiba.co.jp	Toshiba Railway Power Supply Systems System integration (General reference)
http://www.railjournal.com	International Rail Journal Traction choices: overhead ac vs third rail dc Parliamentary report criticises British electrification policy (Article)

Links

This unit links to the following related units:

Unit 4002: Engineering Maths

Unit 4019: Electrical and Electronic Principles

Unit 4022: Electronic Circuits and Devices

Unit 4047: Railway Operations

Unit 4048: Track Design

Unit 4049: Principles of Overhead Power

Unit 4053: Traction and Rolling Stock Systems.

Unit 4051: Introduction to Signalling Systems

Unit Code: H/617/3667

Level: 4

Credits: 15

Introduction

This unit aims to provide students with an underpinning knowledge of signalling, why signalling is provided, and also how it interfaces with other railway engineering disciplines and railway operations.

Students will consider different types of interlocking systems and which train detection systems are used in each type. An appreciation of railway operation will be given when discussing block systems as well as exploring the purpose of signalling from first principles, while considering the necessity for signals and their relationship within the modern railway.

The knowledge and understanding gained in this unit will enable students to make an informed choice should they choose to specialise in signal engineering or, alternatively, a thorough appreciation of the subject should they prefer to pursue other disciplines.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate the meaning of signals and indicators provided on UK railways

LO2 Discuss the merits of various interlocking systems

LO3 Explore the necessity for train detection systems and how they are applied within the signalling system

LO4 Identify different types of block systems for single and double line railways.

Essential Content

LO1 Evaluate the meaning of signals and indicators provided on UK railways

The development of signals

Historical background from hand signalling by 'policemen' to semaphore signals.

Further development with the greater use of electricity

First with power operation, then development of colour light signals in conjunction with more complex interlocking systems.

Signals in the cab

The migration to cab signalling and indicators

The case for removing wayside signals altogether.

LO2 Discuss the relative merits of various interlocking systems

The purpose of interlocking

Historical overview, why it is necessary, what it achieves.

Mechanical interlocking

Principles, use in conjunction with block systems.

Electro-mechanical interlocking

Development from mechanical systems, greater use of electricity within interlocking and wayside signalling.

Electrical interlocking

Types of relay interlockings, comparison with merits of earlier/later interlocking technology, ease of design, installation, test and subsequent modification.

Electronic interlocking

Development of electronic interlockings, principles, management of data, interfacing with other systems, e.g. European Train Control System.

LO3 Explore the necessity for train detection systems and how they are applied within the signalling system

The origin of train detection

Historical overview with early applications

The difference between contacting and non-contacting systems, why it is necessary and what it achieves.

Application of track circuits

Use in conjunction with the absolute block system and subsequent development of the track circuit block system with greater use of centralised control.

Communications Based Train Control (CBTC)

Train detection using radio position reports sent from the train to the wayside equipment as used in moving block systems.

LO4 Identify different types of block systems for single and double line railways.

Block systems

The difference between block systems required for train separation on single line railways and double line railways.

Single line railways

Development from one train working through various systems (staff and token working to acceptance levers) to track circuit block.

Double line railways

Development from time interval working through various systems (absolute block, track circuit block) to moving block systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the meaning of signals and indicators provided on UK railways		
P1 Review the evolution of signaling technology from hand signalling through to cab signalling. **P2** Assess the implications of cab signaling and indicators on wayside signalling.	**M1** Compare and contrast the difference between junction signalling using semaphore signals and colour light signals.	**D1** Critically evaluate the reasons for providing different controls for junction signals, considering the advantages and disadvantages of each.
LO2 Discuss the merits of various interlocking systems		
P3 Explore the development of the interlocking systems and the link between points and signals. **P4** Determine the advantages and disadvantages between mechanical, electro-mechanical, electrical and electronic interlocking systems.	**M2** Assess the use of mechanical signalling in conjunction with block systems.	**D2** Compare the merits of relay interlocking with earlier/later interlocking technology, considering design, installation, test and subsequent modification.

Pass	Merit	Distinction
LO3 Explore the necessity for train detection systems and how they are applied within the signalling system		
P5 Explore the development of train detection systems and the application of track circuits. **P6** Discuss the CBTC system and its importance in communicating the position of the train to the block system wayside equipment.	**M3** Assess the uses of train detection with respect to the interlocking and block systems.	**D3** Investigate the differences between track circuits, train detection and CBTC detection, considering the benefits of each.
LO4 Identify different types of block systems for single and double line railways.		
P7 Differentiate between the principles of the absolute block system and the track circuit block system. **P8** Identify the main characteristics of electric token working for single line railways.	**M4** Produce control tables for aspect controls of a junction signal using the track circuit block system.	**D4** Critically evaluate the differences between the track circuit block and moving block systems, in particular where application of each of the system would have advantages over the other.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ellis, I. (2015) *Ellis' British Railway Engineering Encyclopedia.* 3rd ed.
North Carolina: Lulu Press, Inc.

Hall, C. (2019) *abc Modern Signalling Handbook.* 5th ed.
Shepperton: Ian Allan Publishing.

Woodbridge, P.J. (2018) *A Chronology of UK Railway Signalling 1825 – 2018.*
London: Independent Publishing Network.

Websites

rssb.co.uk	Rail Safety and Standards Board Standards catalogue (General reference)
irse.org	Institution of Railway Signal Engineers Knowledge (General reference)
signalling-and-telecommunications.uk	Signal & Telecommunications UK Trainee revision questions (Training)

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4047: Railway Operations

Unit 4052: Railway Telecommunications

Unit 4053: Traction and Rolling Stock Systems

Unit 4057: Networking

Unit 4058: Strategic Information Systems.

Unit 4070: Command and Control Systems.

Unit 4052: Railway Telecommunications

Unit Code: K/617/3668

Level: 4

Credits: 15

Introduction

Telecommunications is one of the most important areas in the successful running of a railway system. It provides the infrastructure which supports not just the communication between train operators and other members of staff or passengers, but also the signalling which enables the safe control of operational aspects of the railway as well as the monitoring of various parameters, including environmental ones, for security purposes.

This unit focuses on the principles, technology, systems, design, maintenance and troubleshooting of telecommunications systems as they apply in the railway industry. Initially, the unit covers circuits, analogue and digital signals, modulation and multiplexing. A basic communications system is then introduced and analysed, and various technologies are presented: fixed and mobile telephony, copper-based systems, fibre optics, microwave links and satellite communications. This is followed by telecommunications systems, interfacing and operating procedures as they apply to the railway industry. Finally, the unit focuses on all stages of designing, installing, testing, maintaining and troubleshooting a telecommunications system based on a brief specific to the railway industry.

Students who have completed this unit as part of their HNC studies will be very well placed to apply for employment as Telecommunications Advanced Technicians or other similar roles within the rail industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain telecommunications principles and technology fundamentals

LO2 Describe various types of telecommunications systems and technologies

LO3 Explore how telecommunications systems are employed in the railway industry

LO4 Explore the principles of design, installation, commissioning, maintenance and troubleshooting of railway telecommunications systems.

Essential Content

LO1 Explain telecommunications principles and technology fundamentals

Circuits:

Open and closed circuits

Ohm's Law.

Signals:

Electromagnetic (EM) spectrum

Analogue signal characteristics – amplitude, frequency, period, velocity

Digital signal characteristics – amplitude, bit rate, baud rate

Analogue-to-Digital and Digital-to-Analogue Conversion (ADC and DAC), Sampling, digitising, line encoding, data codes.

Modulation:

Analogue carrier modulation – AM, FM, PM

Digital carrier modulation – ASK, FSK, PSK.

Multiplexing:

Frequency, time and wavelength Division Multiplexing (FDM, TDM, WDM).

LO2 Describe various types of telecommunications systems and technologies

Basic communications system:

Transmitter, channel, receiver

Communications channel – wired and wireless

Signal transmission – strength, noise, attenuation, bandwidth, dB, SNR.

Telecommunications technologies:

Public Switched Telephone Network (PSTN)

Mobile/cellular telephony

Fibre optic communications

Free Space Optical (FSO) Communications

Microwave point-to-point links

Satellite communications.

Data communications:

Data flows, encapsulation, collisions

ISO/OSI 7-Layer and TCP/IP Reference Models

Networks (PAN, LAN, MAN, WAN, etc)

The internet.

LO3 **Explore how telecommunications systems are employed in the railway industry**

Railway telecommunications systems:

Communication between railway staff

Traffic safety, traffic reliability and time synchronisation

Customer information systems, passenger alarms, internet, video surveillance.

Interfacing between similar and different telecommunications assets and systems:

Physical interfaces

Systems interfaces.

Telecommunications operating procedures:

Fail-safe operation principles

Emergency procedure responses

Health and safety.

Safety Integrity:

Safety critical systems

Process assurance

Systematic failure integrity

Safety Integrity Levels (SIL)

Controlling hazards during operation

Safe work practice procedures.

LO4 **Explore the principles of design, installation, commissioning, maintenance and troubleshooting of railway telecommunications systems.**

Brief/Application/System Requirements:

Determining specifications

Identifying implications and constraints

Establishing operating requirements.

Telecommunications system design:

Planning based on specifications

Choosing an appropriate telecommunication technology

Producing a telecommunications system design.

Installation Procedures:

Planning

Safeguarding

Installing

Testing

Delivering.

Maintenance:

Determining appropriate maintenance procedures and frequencies.

Troubleshooting:

Fault finding using appropriate techniques and procedures

Repairing, testing, returning to service.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain telecommunications principles and technology fundamentals		
P1 Describe telecommunications principles with respect to circuit design and signals. **P2** Explore the telecommunications technological fundamentals in terms of modulation and multiplexing.	**M1** Compare analogue and digital signals giving, the choice of signal for long-distance communications.	**D1** Investigate the process of ADC and DAC, presenting graphical representations of conversions and effects from sampling and quantisation noise on the recovered analogue signal.
LO2 Describe various types of telecommunications systems and technologies		**LO2 and LO3**
P3 Explain a simple telecommunications system detailing the functions of each stage. **P4** Discuss the effects that a wireless channel has on a telecommunication system's capabilities.	**M2** Illustrate the process of encapsulation and decapsulation in data communications along with which networking devices are associated with each step.	**D2** Analyse the various telecommunications systems used on trains to enable passengers to access the internet describing the factors which affect the quality of service provision.
LO3 Explore how telecommunications systems are employed in the railway industry		
P5 Explain how telecommunications is used to support and enhance traffic safety, traffic reliability and time synchronisation. **P6** Describe what part telecommunications plays in maintaining operational procedures and safety integrity in the railway industry.	**M3** Assess the different types of telecommunications systems used in the railway industry.	

Pass	Merit	Distinction
LO4 Explore the principles of design, installation, commissioning, maintenance and troubleshooting of railway telecommunications systems.		
P7 Explain the process of developing a telecommunications system from design conception through to commissioning. **P8** Discuss the importance of railway telecommunication systems maintenance and troubleshooting.	**M4** Evaluate the impacts that telecommunication system design has on maintenance and troubleshooting.	**D3** Develop a maintenance programme that would reduce the down time of a telecommunications system, highlighting the design features that could significantly impact schedules.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Frenzel, L.E. Jr. (2016) *Principles of Electronic Communication Systems*. 4th ed. New York: McGraw-Hill Education.

Masson, E. and Berbineau, M. (2018) *Broadband Wireless Communications for Railway Applications: For Onboard Internet Access and Other Applications (Studies in Systems, Decision and Control).* Berlin: Springer.

Stallings, W. (2013) *Data and Computer Communications.* 10th ed. Harlow: Pearson.

Yu, F. R. (2018) *Advances in Communications-Based Train Control Systems*. Boca Raton: CRC Press.

Zhong, Z.D., Ai, B. and Zhu, G. (2017) *Dedicated Mobile Communications for High-speed Railway (Advances in High-speed Rail Technology)*. Berlin: Springer.

Websites

theiet.org	The IET Railway Network Railway (General reference)
railjournal.com	International Railway Journal Technology updates (General reference)
railway-technical.com	Railway Technical Technology updates (General reference)

Links

This unit links to the following related units:

Unit 4002: Engineering Maths

Unit 4003: Engineering Science

Unit 4019: Electrical and Electronic Principles

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 4047: Railway Operations

Unit 4053: Traction and Rolling Stock Systems

Unit 4057: Networking

Unit 4058: Strategic Information Systems

Unit 4070: Command and Control Systems

Unit 4071: Introduction to Signalling Systems.

Unit 4053: Traction and Rolling Stock Systems

Unit Code: M/617/3669

Level: 4

Credits: 30

Introduction

Rolling stock (trains) are made up of traction and passenger carriages for people and locomotives and wagons for cargo. Traction and Rolling Stock Systems Advanced Technicians maintain and repair these so they operate safely and efficiently.
Most of the work takes place at night when the railway is closed to the public.

This unit focuses on the knowledge and skills that Traction and Rolling Stock Systems Advanced Technicians must have on the design, construction, maintenance, operation and failure modes of the railway. The unit provides in-depth and detailed technical knowledge of traction and rolling stock systems, subsystems and components, and how they interact. It considers mechanical, electrical, electronic, pneumatic and hydraulic applications. It provides in depth understanding of maintenance procedures and standards as applicable to vehicle type; emphasises the requirement to isolate equipment prior to carrying out maintenance and renewal of traction and rolling stock; delivers knowledge on the requirements of and planning for vehicle overhaul, the physical and systems interfaces between traction and rolling stock assets and systems, and other aspects of the railway, the operating requirements, and the implications and constraints of these.

Upon completing this unit, Traction and Rolling Stock Systems Advanced Technicians will also be able to interrogate and understand advanced diagnostic systems, and analyse data packages to identify and understand faults and potential faults and defects. Moreover, they will also be able to implement corrective actions to enhance vehicle reliability and to recommend design alterations and amendments to maintenance procedures in accordance with current rail legislation.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain traction and rolling stock systems, subsystems and components and how they interact

LO2 Explore the different techniques and methods used to construct, install and manage traction and rolling stock systems and avoid failures

LO3 Explain the principles required to maintain, renew and troubleshoot the traction and rolling stock systems

LO4 Explore effective maintenance procedures and standards relative to a particular type of traction and rolling stock.

Essential Content

LO1 Explain traction and rolling stock systems, subsystems and components and how they interact

Systems and components:

Mechanical components and systems

Electrical components and systems

Hydraulic and pneumatic components and systems

Ancillary equipment

Heat Ventilation and Air Conditioning (HVAC)

Vehicle trim and fittings

Other vehicle equipment and furnishings

Electronic communication systems and associated equipment.

LO2 Explore the different techniques and methods used to construct, install and manage traction and rolling stock systems and avoid failures

Techniques and methods used to construct, install and manage:

Suspension and tilt systems

Stock braking systems

Axles, wheels and bearings

AC and DC electric power collection and transmission

Diesel hydraulic and diesel electric power generation and transmission in overground trains.

Techniques and methods used to avoid railway asset, equipment, process and systems failures:

Data analysis

Health and safety precautions

Maintenance schedules

Fault testing and diagnosis

Use of appropriate tools and equipment

Troubleshooting techniques

Maintenance record and fault-logging system.

LO3 **Explain the principles required to maintain, renew and troubleshoot the traction and rolling stock systems**

Techniques and methods used to maintain, renew and troubleshoot:

Suspension and tilt systems

Braking systems

Axles, wheels and bearings

AC and DC electric power collection and transmission

Overground train diesel hydraulic and diesel electric power generation and transmission.

Overground and underground vehicle passenger comfort, safety and security:

Closed Circuit Television Systems (CCTV)

Heating, Ventilation and Air Conditioning Systems

Passenger information systems

Interior and exterior, saloon and cab door systems

Toilet systems

Vehicle trim

Traction motors.

System knowledge

Various control systems and components

Principles of systems functions

Correct operating procedures.

LO4 **Explore effective maintenance procedures and standards relative to a particular type of traction and rolling stock.**

Carry out maintenance and overhaul activities:

Isolation of equipment prior to carrying out maintenance for health and safety reasons

Operating in a timely and specified sequence

Specific to the equipment being maintained

Set up and apply the appropriate test equipment

Troubleshooting and overcoming problems

Plan and communicate the maintenance activities to ensure minimal disruption to normal working

Replenish levels of fluid power components

Fault-finding activities on traction and rolling stock systems, process-controller systems and electrical equipment

Ensure activities comply with relevant standards.

Dismantling, re-assembling and replacing equipment:

Use appropriate operating and maintenance procedures for equipment and components.

Maintenance of connections and fittings:

In accordance with maintenance schedule

Regular mechanical connections checks

Ensure secure electrical and electronic connections

Ensure secure hydraulic and pneumatic connections.

Undertake testing activities:

Specific to item tested.

Follow correct handover procedures

Documentation sign-off

Approval of service.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain traction and rolling stock systems, subsystems and components and how they interact		
P1 Describe traction and rolling stock systems and components. **P2** Discuss the function of the various components and systems and how they interact.	**M1** Illustrate the function of the various electronic communication systems and their associated equipment that operate with the traction and rolling systems.	**D1** Critically analyse how the various traction and rolling stock systems interface, identifying any specific systems that interact with passengers.
LO2 Explore the different techniques and methods used to construct, install and manage traction and rolling stock systems and avoid failures		
P3 Identify the construction stages, techniques and procedures used for traction and rolling stock systems. **P4** Assess why it is important to follow health and safety precautions when constructing, installing and managing traction and rolling stock systems.	**M2** Evaluate the various techniques and methods used to construct, install and manage traction and rolling stock systems with regard to failure prevention.	**D2** Develop a maintenance schedule aimed at optimising rolling stock operation while avoiding railway asset, equipment, process and systems failures.

Pass	Merit	Distinction
LO3 Explain the principles required to maintain, renew and troubleshoot the traction and rolling stock systems		
P5 Describe the importance of following the maintenance schedule when maintaining and renewing traction and rolling stock systems. **P6** Explain what approaches are used when troubleshooting traction and rolling stock system issues.	**M3** Explain the importance of and the principles required to undertake and direct the maintenance of Heating, Ventilation and Air Conditioning Systems.	**D3** Analyse how AC and DC electric power collection and transmission systems maintenance must be undertaken.
LO4 Explore effective maintenance procedures and standards relative to a particular type of traction and rolling stock.		
P7 Explain why it is necessary to isolate equipment prior to carrying out maintenance. **P8** Explain how frequent and timely maintenance of the railway helps prevent railway asset, equipment, process and systems failures especially with regard to logging faults and findings.	**M4** Explain why electrostatic discharge (ESD) precautions must be taken when working on or close to sensitive electronic communications components.	**D4** Explain two types of testing activities undertaken to confirm that traction and rolling stock systems operate correctly.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Iwnicki, S. (Ed.) *Handbook of Railway Vehicle Dynamics*. Boca Raton: CRC Press.

Pyrgidis, C.N. (2018). *Railway Transportation Systems: Design, Construction and Operation*. Boca Raton: CRC Press.

Websites

http://www.railway-technical.com	Railway – Technical Trains (General reference)
http://www.imeche.org/	IMechE Railway (General reference)
http://www.hitachirail-eu.com	Hitachi Rail Depots (General reference)

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 4016: Instrumentation and Control Systems

Unit 4017: Quality and Process Improvement

Unit 4019: Electrical and Electronic Principles

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit 4047: Railway Operations

Unit 4048: Track Design

Unit 4050: Principles of Electrification

Unit 4052: Railway Telecommunications

Unit 4054: Passenger Safety and Security

Unit 4070: Command and Control Systems

Unit 4071: Introduction to Signalling Systems.

Unit 4054: Passenger Safety and Security

Unit Code: H/617/3670

Level: 4

Credits: 15

Introduction

Essential to the ability for people to travel the length and breadth of the country is the provision of a safe, reliable and resilient transport network. Most countries across the world, including the UK, the USA, China, Japan and Germany, benefit from extensive rail networks. Successfully operated, these networks help to reduce traffic congestion on highways, reduce the need for air travel, promote commerce and benefit the environment.

Ensuring that the overground passenger rail networks are comfortable, safe and secure encourages their continued use by passengers. Passengers must receive clear information on approaching stations, disruptions to rail services and instructions in the event of an emergency while travelling. Overground rail carriages are ventilated and maintained at a suitable temperature for users. Customers board and alight rail carriages speedily, mostly using automatic doors, and are monitored using closed-circuit television whilst on trains to ensure their own safety.

This unit enables students to develop their knowledge of the purpose, installation, use and maintenance of different types of passenger comfort, safety and security systems. Passenger information systems and the communication systems are examined and maintained along with other systems integral to the safety and comfort of passengers. These systems include railway doors, Heating Ventilation and Air Conditioning (HVAC), toilets and the vehicle trim used on rail vehicles.

The unit introduces both the electrical and pneumatic control systems used on overground rail vehicles and, on completion, the student will have a greater understanding of key passenger safety and security systems and how they function.

On successful completion of this unit students will be able to prepare an engineering design specification that fulfils a stakeholder’s design brief, recommend reliability improvements and present these to an audience. Students will also be able to demonstrate an understanding of the required legislation in the areas of passenger safety and security and use this understanding to formulate solutions to overcome maintenance issues. Students who have completed this unit as part of their HNC studies will be well placed to apply for employment as Rolling Stock Testing Support, Rolling Stock Technical Engineer or other similar roles within the rail industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain how modifications to an existing fleet of rolling stock with improved passenger safety or security equipment can be made in response to a stakeholder's design brief

LO2 Investigate the feasibility and cost implications of installing a universal access toilet in an area currently used for passenger seating

LO3 Describe possible solutions that would enable a train maintenance facility to repair, modify and re-gas its own HVAC systems on site

LO4 Analyse possible design solutions that propose a reliability improvement to an exterior saloon door or cab door system.

Essential Content

LO1 **Explain how modifications to an existing fleet of rolling stock with improved passenger safety or security equipment can be made in response to a stakeholder's design brief**

Planning techniques used to prepare a design solution:

Definition of any design constraints, specifications, assumptions and functions

Use of relevant engineering/industry standards and specifications within the design process

Use of ergonomic and aesthetic standards and specifications in the design of passenger equipment and comfort

Planning the design task using flow charts, Gantt charts, network and critical path analysis.

Design process:

Process development, steps to consider from start to finish.

Key components of passenger information systems their operation and function:

Public address systems

Passenger information and safety signage and displays

Passenger emergency alarms

Communication networks

Coach design variations due to passenger class requirements

Seat reservation plan and display.

Components, function and technical requirements of closed-circuit television systems:

Explain the different types of cameras and systems, their characteristics, capabilities and positioning, including communication networks.

Appropriate use of closed-circuit television to respect privacy:

Data Protection Act 1988

Human Rights Act 1988

Freedom of Information Act 2000

Impact of the Information Commissioner's Code of Practice on the operation of closed-circuit television systems and the requirements of privacy zones.

Understanding customer/stakeholder requirements:

Converting customer requests to a list of objectives and constraints

Interpretation of design requirements.

Market analysis of existing products and competitors

Aspects of innovation and performance management in decision-making.

LO2 **Investigate the feasibility and cost implications of installing a universal access toilet in an area currently used for passenger seating**

Components of a train toilet system:

Waste and fresh water systems

Soap dispenser and hygiene systems

Processors

Vacuum control

Cabling

Pipework

Call-for-aid systems

Toilet module size and space requirements and optimisation

Fresh water replenishment and waste tank emptying requirements.

Seating loss and passenger capacity:

Potential revenue loss

Passenger dissatisfaction.

Legislation and regulations:

Specification for toilets of railway vehicles

Accessibility requirement

Technical specification for interoperability relating to persons with reduced mobility

Association of Train Operating Companies (ATOC) guidance.

Design process:

Process development

Steps to consider from start to finish.

Planning techniques used to prepare a design solution:

Definition of any design constraints, assumptions specifications and functions

Use of relevant engineering/industry standards within the design process

Planning the design task using flow charts, Gantt charts, network and critical path analysis.

LO3 **Describe possible solutions that would enable a train maintenance facility to repair, modify and re-gas its own HVAC systems on site**

Legislation and regulations related to:

Refrigerant handling

Storage and disposal

Competence

Safe systems of work, including potential hot work permits.

Working on or around live electrical systems:

Importance of safety

Risk management

Understanding of the Electricity at Work Regulations 1989.

Working on or around pressurised systems:

Importance of safety

Risk management

Understanding the Pressure Equipment Regulations 1999 (PER)

Understanding the Pressure Systems Safety Regulations 2000 (PSSR).

LO4 **Analyse possible design solutions that propose a reliability improvement to an exterior saloon door or cab door system.**

Communication and post-presentation review:

Selection of presentation tools

Analysis of presentation feedback

Strategies for improvement based on feedback.

Key components of exterior saloon and cab door:

Importance of correct set-up

Electric/electro-pneumatic sliding and plug doors

Lock mechanisms and their control systems

Safety systems both local to the door and train wide.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explain how modifications to an existing fleet of rolling stock with improved passenger safety or security equipment can be made in response to a stakeholder's design brief</td><td rowspan="2">D1 Critically Analyse potential planning and design requirements, giving a justification for the chosen method.</td></tr>
<tr><td>P1 Describe how modifications to improve passenger safety or security can be made from a given design brief.

P2 Discuss how a customer's request can be converted to a list of design objectives and constraints.</td><td>M1 Analyse how the existing external rolling stock design could present limitations on the design of the internal equipment.</td></tr>
<tr><td colspan="2">LO2 Investigate the feasibility and cost implications of installing a universal access toilet in an area currently used for passenger seating</td><td rowspan="2">D2 Evaluate the implications that the installation of a toilet will have on the HVAC system's design with regards to capacity and HSE requirements.</td></tr>
<tr><td>P3 Explore the feasibility of carrying out the proposed task.

P4 Explain the cost implications of the scope of work.</td><td>M2 Examine the optimisation process required to maximise the area taken up by the toilet whilst minimising the impact on the original passenger seating area.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Describe possible solutions that would enable a train maintenance facility to repair, modify and re-gas its own HVAC systems on site		**D3** Evaluate the proposed maintenance solution with regards to the option of outsourcing.
P5 Outline the requirements of servicing HVAC units in a depot environment. **P6** Illustrate possible design solutions. **P7** Identify the legal and safety implications of carrying out the full scope of maintenance work.	**M3** Analyse the time and cost implications of the maintenance solution.	
LO4 Analyse possible design solutions that propose a reliability improvement to an exterior saloon door or cab door system.		**D4** Justify potential improvements to the presented design solution, based on reflection and feedback obtained from the presentation.
P8 Illustrate possible design solutions to improve the reliability of an exterior saloon or cab door system. **P9** Propose a reliability improvement to either an exterior saloon or cab door system. **P10** Present the recommended design solution to the identified audience.	**M4** Compare the effectiveness of the possible design solutions.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bonnett, C. F. (2005) *Practical Railway Engineering*. 2nd Ed. London: Imperial College Press.

Websites

http://www.transportfocus.org.uk	Transport Focus Future Merseyrail rolling stock – what passengers want (Publication)
http://www.hse.gov.uk	Health and Safety Commission Rail safety: Proposals for Regulations on train protection systems and mark 1 rolling stock (Report)
orr.gov.uk	Office of Rail and Road Passenger Safety (General reference)

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4009: Materials, Properties and Testing

Unit 4016: Instrumentation and Control Systems

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit 4047: Railway Operations

Unit 4052: Railway Telecommunications

Unit 4053: Traction and Rolling Stock Systems

Unit 4055: Management and Operations.

Unit 4055: Management and Operations

Unit Code: D/508/0488

Level: 4

Credits: 15

Introduction

The aim of this unit is to help students understand the difference between the function of a manager and the role of a leader. Students will consider the characteristics, behaviours and traits which support effective management and leadership. In addition, this unit will introduce the concept of operations as both a function and a process which all organisations must adopt to conduct business. Students will be introduced to contemporary and historical theories and concepts which will support their learning for this unit.

On successful completion of this unit students will have developed sufficient knowledge and understanding of how management and operations make a positive, efficient and effective contribution to an organisation at a junior level. This could be in the role of a team leader or managing a specific aspect of an operation function and/or process.

Underpinning all aspects of the content for this unit you will consider topics under two broad headings: management and operations.

*This unit is the same unit as *Unit 4: Management Operations* in the *Pearson BTEC Higher Nationals in Business*

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Differentiate between the role of a leader and the function of a manager

LO2 Apply the role of a leader and the function of a manager in given contexts

LO3 Demonstrate an appreciation of the role leaders and managers play in the operations function of an organisation

LO4 Demonstrate an understanding of the relationship between leadership and management in a contemporary business environment.

Essential Content

LO1 **Differentiate between the role of a leader and the function of a manager**

Management theory:

Contemporary and seminal theories of management such as management by objectives, classical management theories, behavioural theory and contingency theory.

Leadership vs management:

The definitions and differences of both a leader and a manager

Management functions such as planning, organising, controlling and directing

Theories of leadership traits, style and contingency

Transformational and Transactional Leadership

Action Centred Leadership

'Hard' management skills and 'soft' leadership skills.

LO2 **Apply the role of a leader and the function of a manager in given contexts**

How situations affect the role of a leader and function of a manager:

Situational leadership, systems leadership, task or relationship-orientated approaches

The application of chaos theory and management by objectives.

LO3 **Demonstrate an appreciation of the role leaders and managers play in the operations function of an organisation**

Theories of operations and operations management:

Six sigma, lean production and queuing theory.

Different operations management approaches:

The use of different management approaches: Principles of Total Quality Management (TQM), Just-in-Time Inventory and the concept of continuous improvement (Kaizen).

Operational functions:

Control and Distribution Systems

Transformation of raw material into finished goods/services

Process design

Capacity management

Logistics and inventory management

Scheduling.

LO4 **Demonstrate an understanding of the relationship between leadership and management in a contemporary business environment.**

Different dimensions of contemporary business environment:

The relationship that leadership and management have in the context of corporate social responsibility; culture, values, ethics and sustainability

The relationship with stakeholders and meeting stakeholder expectations in the context of encouraging, developing and sustaining entrepreneurship and intrapreneurship.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Differentiate between the role of a leader and the function of a manager		**LO1 and LO2**
P1 Define and compare the different roles and characteristics of a leader and a manager.	**M1** Analyse and differentiate between the role of a leader and function of a manager by effectively applying a range of theories and concepts.	**D1** Critically analyse and evaluate the different theories and approaches to leadership in given contexts.
LO2 Apply the role of a leader and the function of a manager in given contexts		
P2 Examine examples of how the role of a leader and the function of a manager apply in different situational contexts. **P3** Apply different theories and models of approach, including situational leadership, systems leadership and contingency.	**M2** Assess the strengths and weaknesses of different approaches to situations within the work environment.	

Pass	Merit	Distinction
LO3 Demonstrate an appreciation of the role leaders and managers play in the operations function of an organisation		**LO3 and LO4**
P4 Explain the key approaches to operations management and the role that leaders and managers play. **P5** Explain the importance and value of operations management in achieving business objectives.	**M3** Evaluate how leaders and managers can improve efficiencies of operational management to successfully meet business objectives.	**D2** Critically evaluate application of operations management and factors that impact on the wider business environment.
LO4 Demonstrate an understanding of the relationship between leadership and management in a contemporary business environment.		
P6 Assess the factors within the business environment that impact upon operational management and decision-making by leaders and managers.	**M4** Analyse how these different factors affect the business environment and wider community.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Hill, A. and Hill, T. (2017) *Essential Operations Management.* 2nd Ed. London: Palgrave.

Pettinger, R. (2007) *Introduction to Management.* 4th ed. London: Palgrave Macmillan.

Schedlitzki, D. and Edwards, G. (2014) *Studying Leadership: Traditional and Critical Approaches*. London: SAGE.

Slack, N., Brandon-Jones, A. and Johnston, R. (2013) *Operations Management.* 7th ed. Harlow: Pearson.

Links

This unit links to the following related units:

Unit 4012: Engineering Management

Unit 4047: Railway Operations.

Unit 4056: Programming

Unit Code: D/615/1618

Level: 4

Credits: 15

Introduction

Programming involves describing processes and procedures which are derived from algorithms. The ability to program is what sets apart a developer and an end user. Typically, the role of the developer is to instruct a device (such as a computer) to carry out instructions; the instructions are known as source code and is written in a language that is converted into something the device can understand. The device executes the instructions it is given.

Algorithms help to describe the solution to a problem or task; by identifying the data and the process needed to represent the problem or task *and* the set of steps needed to produce the desired result.

Programming languages typically provide the representation of both the data and the process; they provide control constructs and data types (which can be numbers, words, and objects, and be constant or variable).

The control constructs are used to represent the steps of an algorithm in a convenient yet unambiguous fashion. Algorithms require constructs that can perform sequential processing, selection for decision-making, and iteration for repetitive control. Any programming language that provides these basic features can be used for algorithm representation.

This unit introduces students to the core concepts of programming with an introduction to algorithms and the characteristics of programming paradigms.

Among the topics included in this unit are: introduction to algorithms, procedural, object-orientated & event-driven programming, security considerations, the integrated development environment and the debugging process.

On successful completion of this unit students will be able to design and implement algorithms in a chosen language within a suitable Integrated Development Environment (IDE). This IDE will be used to develop and help track any issues with the code.

As a result, they will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation which are crucial for gaining employment and developing academic competence.

*This unit is the same unit as *Unit 1: Programming in the Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

By the end of this unit students will be able to:

LO1 Define basic algorithms to carry out an operation and outline the process of programming an application

LO2 Explain the characteristics of procedural, object-orientated and event-driven programming, conduct an analysis of a suitable Integrated Development Environment (IDE)

LO3 Implement basic algorithms in code using an IDE

LO4 Determine the debugging process and explain the importance of a coding standard.

Essential Content

LO1 **Define basic algorithms to carry out an operation and outline the process of programming an application**

Algorithm definition:

Writing algorithms to carry out an operation, e.g. Bubble sort

The relationship between algorithms and code

The generation process of code; the roles of the pre-processor, compiler and linker, interpreter.

LO2 **Explain the characteristics of procedural, object-orientated and event-driven programming. Conduct an analysis of a suitable Integrated Development Environment (IDE)**

Characteristics of code:

Definitions of data types (the role of constants/variables), methods (including input/output), control structures, iteration, scope, parameter passing, classes, inheritance and events

Key components of an IDE with a brief explanation each component.

LO3 **Implement basic algorithms in code using an IDE**

Implementation:

Developing simple applications which implements basic algorithms covered in LO1, using the features of a suitable language and IDE. Consider possible security concerns and how these could be solved.

LO4 **Determine the debugging process and explain the importance of a coding standard.**

Review and reflection:

Documentation of the debugging process in the IDE, with reference to watch lists, breakpoints and tracing

How the debugging process can be used to help developers fix vulnerabilities, defects and bugs in their code

What a coding standard is and its benefits when writing code.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Define basic algorithms to carry out an operation and outline the process of programming an application		
P1 Provide a definition of what an algorithm is and outline the process in building an application.	**M1** Determine the steps taken from writing code to execution.	**D1** Examine the implementation of an algorithm in a suitable language. Evaluate the relationship between the written algorithm and the code variant.
LO2 Explain the characteristics of procedural, object-orientated and event-driven programming, conduct an analysis of a suitable Integrated Development Environment (IDE)		
P2 Give explanations of what procedural, object-orientated and event-driven paradigms are; their characteristics and the relationship between them.	**M2** Analyse the common features that a developer has access to in an IDE.	**D2** Critically evaluate the source code of an application which implements the programming paradigms, in terms of the code structure and characteristics.
LO3 Implement basic algorithms in code using an IDE		
P3 Write a program that implements an algorithm using an IDE.	**M3** Use the IDE to manage the development process of the program.	**D3** Evaluate the use of an IDE for development of applications contrasted with not using an IDE.
LO4 Determine the debugging process and explain the importance of a coding standard.		
P4 Explain the debugging process and explain the debugging facilities available in the IDE. **P5** Outline the coding standard you have used in your code.	**M4** Evaluate how the debugging process can be used to help develop more secure, robust applications.	**D4** Critically evaluate why a coding standard is necessary in a team as well as for the individual.

Note

This unit does not specify which programme language should be used to deliver this content – this decision can be made by the tutor.

Examples of languages that are used in industry are C#, Python, Ruby, Java, but any language which will allow the student to achieve the Learning Outcomes is acceptable.

Print Resources

Aho, A. V. et al. (1987) *Data Structures and Algorithms*. 1st ed.
Boston: Addison-Wesley.

Hunt, A. et al. (2000) *The Pragmatic Programmer: From Journeyman to Master.*
1st ed. Boston: Addison-Wesley.

McConnell, S. (2004) *Code Complete: A Practical Handbook of Software Construction*.
2nd ed. Harlow: Microsoft Press.

Links

This unit links to the following related units:

Unit 4057: Networking

Unit 4058: Strategic Information Systems

Unit 4059: Computer Systems Architecture.

Unit 4057: Networking

Unit Code: H/615/1619

Level: 4

Credits: 15

Introduction

Computer networks are the driving force behind the evolution of computer systems and allow users to access data, hardware and services regardless of their location. Being knowledgeable about the underlying principles of networking is of vital importance to all IT professionals. Networking is an environment that is increasingly complex and under continuous development.

Complex computer networking has connected the world by groups of small networks through internet links to support global communications. It supports access to digital information anytime, anywhere using many applications like e-mail, audio and video transmission, including the World Wide Web, and this has opened the floodgates to the availability of information.

The aim of this unit is to provide students with wider background knowledge of computer networking essentials, how they operate, protocols, standards, security considerations and the prototypes associated with a range of networking technologies.

Students will explore a range of hardware, with related software, and will configure and install these to gain knowledge of networking systems. A range of networking technologies will be explored to deliver a fundamental knowledge of Local Area Networking (LAN), Wide Area Networking (WAN) and their evolution to form large-scale networks and the protocol methodologies relating to IP data networks will be explored.

On successful completion of this unit students will gain knowledge and skills to successfully install, operate and troubleshoot a small network; and the operation of IP data networks, router, switching technologies, IP routing technologies, IP services and basic troubleshooting. Supporting a range of units in the Higher National suite, this unit underpins the principles of networks for all and enables students to work towards their studies in vendor units, if applicable.

Students will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation, which are crucial for gaining employment and developing academic competence.

*This unit is the same unit as *Unit 2: Networking* in the *Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine networking principles and their protocols

LO2 Explain networking devices and operations

LO3 Design efficient networked systems

LO4 Implement and diagnose networked systems.

Essential Content

LO1 **Examine networking principles and their protocols**

Role of networks:

Purpose, benefits, resource implications, communications, working practice, commercial opportunity, information sharing, collaboration.

System types:

Peer-based, client-server, cloud, cluster, centralised, virtualised.

Networking standards:

Conceptual models e.g. OSI model, TCP/IP model; standards: e.g. IEEE 802.x.

Topology:

Logical e.g. Ethernet, Token Ring; physical e.g. star, ring, bus, mesh, tree, ring.

Protocols:

Purpose of protocols; routed protocols e.g. IPv4, IPv6, IPv6 addressing, Global unicast, Multicast, Link local, Unique local, EUI 64, Auto configuration, FTP, HTTP, SMTP, POP3, SSL; management of protocols for addressing.

LO2 **Explain networking devices and operations**

Networking devices:

Servers; hub, routers; switches; multilayer switch, firewall, HIDS, repeaters; bridges; wireless devices; access point (wireless/wired), content filter, Load balancer, Modem, Packet shaper, VPN concentrator.

Networking software:

Client software, server software, client operating system, server operating system, Firewall.

Server type:

Web, file, database, combination, virtualisation, terminal services server.

Server selection:

Cost, purpose, operating system requirement.

Workstation:

Hardware e.g. network card, cabling; permissions; system bus; local-system architecture e.g. memory, processor, I/O devices.

LO3 **Design efficient networked systems**

Bandwidth:

Expected average load; anticipated peak load; local internet availability; cost constraints, throughput.

Users:

Quality expectations, concept of system growth.

Networking services and applications:

DHCP; static vs dynamic IP addressing, reservations, scopes, leases, options (DNS servers, Suffixes), IP helper, DHCP relay, DNS records, Dynamic DNS.

Communications:

Suited to devices, suited to users, supportive of lifestyle desires, supportive of commercial requirements, security requirements, quality of service needs.

Scalable:

Able to support device growth, able to support addition of communication devices, able to cope with bandwidth use and trend changes, protocol utilisation, addressing.

Selection of components:

Supporting infrastructure needs; supporting connectivity requirements.

LO4 **Implement and diagnose networked systems.**

Devices:

Installation of communication devices, allocation of addresses, local client configuration, server configuration, server installation, security considerations.

Verification of configuration and connectivity:

Installation of internet work communication medium, ping, extended ping, traceroute, telnet, SSH.

System monitoring:

Utilisation, bandwidth needs, monitoring user productivity and security of the system.

Maintenance schedule:

Backups, upgrades, security, auditing.

Diagnose and resolve layer 1 problems:

Framing, CRC, Runts, Giants, Dropped packets, late collisions, Input/Output errors.

Policy review:

Bandwidth, resource availability.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine networking principles and their protocols		**LO1 and LO2**
P1 Discuss the benefits and constraints of different network types and standards. **P2** Explain the impact of network topology, communication and bandwidth requirements.	**M1** Compare common networking principles and how protocols enable the effectiveness of networked systems.	**D1** Considering a given scenario, identify the topology protocol selected for the efficient utilisation of a networking system.
LO2 Explain networking devices and operations		
P3 Discuss the operating principles of networking devices and server types. **P4** Discuss the inter-dependence of workstation hardware with relevant networking software.	**M2** Explore a range of server types and justify the selection of a server, considering a given scenario regarding cost and performance optimisation.	
LO3 Design efficient networked systems		
P5 Design a networked system to meet a given specification. **P6** Test and evaluate the design to meet the requirements and analyse user feedback.	**M3** Install and configure network services and applications on your choice.	**D2** Design a maintenance schedule to support the networked system.
LO4 Implement and diagnose networked systems.		
P7 Implement a networked system based on a prepared design. **P8** Document and analyse test results against expected results.	**M4** Recommend potential enhancements for the networked systems.	**D3** Use critical reflection to evaluate own work and justify valid conclusions.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Burgess, M. (2003) *Principles of Network and System Administration*. 2nd Ed. London: John Wiley and Sons Ltd.

Hallberg, B. (2005) *Networking: A Beginner's Guide*. 4th Ed. New York: Osborne/McGraw-Hill US.

Limoncelli, T. and Hogan, C. (2001) *The Practice of System and Network Administration*. Boston: Addison-Wesley.

Lowe, D. (2005) *Networking All-in-One Desk Reference for Dummies*. 2nd Ed. Hungry Minds Inc.

Olifer, N. and Olifer, V. (2005) *Computer Networks: Principles, Technologies and Protocols for Network Design*. London: John Wiley and Sons Ltd.

Stallings, W. (2003) *Data and Computer Communications*. 7th Ed. New Jersey: Prentice Hall.

Subramanian, M. (2000) *Network Management: An Introduction to Principles and Practice.* Boston: Addison-Wesley.

Tanenbaum, A. (2002) *Computer Networks*. New Jersey: Prentice Hall PTR.

Links

This unit links to the following related units:

Unit 4052: Railway Telecommunications

Unit 4056: Programming

Unit 4058: Strategic Information Systems

Unit 4059: Computer Systems Architecture.

Unit 4058: Strategic Information Systems

Unit Code: A/615/1626

Level: 4

Credits: 15

Introduction

Information is the most valuable resource that an organisation possesses. The effective gathering, protection, analysis, processing and dissemination of information is vital to the success of any organisation. As globalisation and the 24-hour economy develop and increase, organisations must ensure that their information systems are reliable, efficient and able to cope with rapid change.

This unit introduces students to the importance of information to organisations. It will examine how systems can be used to support core business functions and enable organisations to be more productive and competitive within the global marketplace.

Students will be required to analyse the information needs of an organisation at different levels and within different functional areas. It is important that computing professionals are able to understand how an organisation works and how it uses information in order to be able to design, implement, maintain and manage secure information systems to support its operations.

Among the topics included in this unit are understanding organisations in terms of their information needs and the variances within different functional areas. Examination of different information systems at the operational, tactical and strategic levels will be required, in addition to evaluating their effectiveness and role in terms of decision making and gaining competitive advantage.

On successful completion of this unit students will have an insight into the types of systems and technologies available for effective information processing. Critical analysis will also be used to examine the integrated role that each of these play in contributing to the efficiency and competitiveness of organisations.

As a result students will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation, which are crucial for gaining employment and developing academic competence.

*This unit is the same unit as *Unit 7: Strategic Information Systems* in the *Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

By the end of this unit students will be able to:

LO1 Analyse the information requirements of organisations

LO2 Discuss the types of information systems that are used within all levels of an organisation

LO3 Demonstrate the use of an information system to produce management information

LO4 Evaluate the effectiveness of strategic information systems.

Essential Content

LO1 **Analyse the information requirements of organisations**

Functional area information requirements:

Finance and accounts for payroll, pensions, supplier payments and invoicing etc., human resources e.g. employee records, personnel data, appraisals, CPD etc., stock control, sales, marketing, research and development, production, distribution, IT, customer service and administration.

Information needs:

How different functional areas use and process data effectively; the integration of data and information within an organisation.

Requirements analysis:

The inputs, outputs and processing activities; information distribution requirements e.g. by location, department, individual/customer.

LO2 **Discuss the types of information systems that are used within all levels of an organisation**

Information systems types:

Business information systems, decision support systems, management information systems, strategic/executive information systems, office information systems, transaction processing systems, expert systems, global information systems, data warehouse systems, enterprise systems, enterprise resource planning systems, integrated information systems.

Categories of information systems:

Operational, tactical and strategic information systems.

Information and data:

Definition of information and data, sources of information, information requirements and the needs for information at different levels within an organisation; storing information and its importance with regard to security, accuracy and relevance; outputs e.g. payroll, invoicing, ordering, bookings, stock control, personnel records, goods tracking, decision-making, marketing, customer service.

LO3 **Demonstrate the use of an information system to produce management information**

Management information:

Reports e.g. sales report, college enrolment statistics, marketing analysis (brick v click), trends in the market, competition and market share.

Gathering information:

Defining requirements; establishing sources of information; defining other factors to be considered e.g. constraints and access to information.

Selecting information:

Analysis of information in terms of validity, accuracy, currency and relevancy; identifying and rationalising meaningful information from data sets.

Uses:

Proficiency in terms of accessing quality information that can be used for decision-making, problem-solving, predictions, trending and forecasting.

LO4 **Evaluate the effectiveness of strategic information systems.**

Models for strategic information systems:

Porters Competitive Advantage and Wiseman's Strategic Planning Process.

Competitive advantage:

How can competitive advantage be measured and attributed to the implementation of a strategic information system?

Gaining competitive advantage:

Delivering a differentiated product or service; delivering a product or service at a lower cost; specific segmentation of the market e.g. targeted marketing to specific target audiences; innovative product or service design and implementation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse the information requirements of organisations		**D1** Evaluate the inputs, outputs and processing activities of a selected organisation.
P1 Discuss the information needs and requirements for the functional departments of an organisation. **P2** Produce an input/output (I/O) diagram to represent the data and information requirements of a functional department.	**M1** Compare and contrast different processing activities that occur within functional departments within an organisation.	
LO2 Discuss the types of information systems that are used within all levels of an organisation		
P3 Describe the function of different information systems. **P4** Discuss the information needs required at differing levels within an organisation.	**M2** Analyse the effectiveness of information systems at the operational, tactical and strategic levels within an organisation.	**D2** Differentiate between the function and purpose of information systems at different levels within an organisation.
LO3 Demonstrate the use of an information system to produce management information		
P5 Demonstrate the use of an information system for management reporting purposes. **P6** Discuss the importance of an organisation having data and information that is current, valid and accurate.	**M3** Analyse the constraints that an organisation can face when gathering data and information.	**D3** Critique, with examples, how a given organisation can use information for effective decision-making and forecasting.
LO4 Evaluate the effectiveness of strategic information systems.		
P7 Identify different models that can be applied to strategic information systems.	**M4** Justify the ways in which an organisation can obtain competitive advantage within a global market.	**D4** Evaluate how strategic information systems can contribute to the competitiveness of organisations.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Peppard, J. (2016) *The Strategic Management of Information Systems: Building a Digital Strategy*. 4th Ed. New York: John Wiley & Sons.

Robson, W. (1997) *Strategic Management and Information Systems: An Integrated Approach*. 2nd Ed. London: Prentice Hall.

Ward, J. (2002) *Strategic Planning for Information Systems*. 3rd Ed. London: John Wiley & Sons.

Whitely, D. (2013) *An Introduction to Information Systems*. Oxford: Palgrave Macmillan.

Websites

it.toolbox.com	ToolBox.com Strategic Information System Toolbox (Wiki)
http://www.mbaknol.com	MBA Knowledge Base Strategic Information Systems (Article)

Links

This unit links to the following related units:

Unit 4056: Programming

Unit 4057: Networking

Unit 4059: Computer Systems Architecture.

Unit 4059: Computer Systems Architecture

Unit Code: J/615/1628

Level: 4

Credits: 15

Introduction

As technology develops, it is important to have a working foundation on which to build your knowledge. Despite hardware and software being constantly updated and seemingly becoming more complex, students with a solid, underpinned knowledge about computer systems architecture will not only be able to answer questions like, ‘How does a central processor work?’, ‘What does an operating system do?’, ‘How is information stored?’, ‘What is an instruction set?’ and ‘How do I actually connect to the internet?’, but will also be able to transfer and apply their knowledge and skill to many other areas.

This unit introduces students to the foundations of computer systems architecture together with the integrated hardware and software components and subsystems that enable and allow data to be input, processed and output. The unit further explores the concepts of operating systems, hardware management and computer networks together with the practical skills needed to diagnose, troubleshoot and maintain computer systems taking the security of these systems into consideration.

Among the topics included in this unit are: CPUs, memory, input & output devices, ALU operations, program execution, operating systems (including kernel, file systems, API and system calls), hardware management, installation, firmware, device drivers, networking (including OSI and TCP/IP models), error and information gathering, fault diagnostics, security and problem resolution.

On successful completion of this unit, students will be able to explain the purpose and role of operating systems, the relationship between the subsystems embedded within a central processing unit, the core hardware and software components associated with computer operations and be able to configure the hardware and systems needed to establish a computer network together with practical diagnostic and troubleshooting techniques. As a result they will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation which are crucial for gaining employment and developing academic competence.

*This unit is the same unit as *Unit 8: Computer System Architecture* in the *Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the relationships between hardware components and the subsystems used in a computer system

LO2 Categorise the key features and services provided by different computer operating systems and hardware

LO3 Use network communication technology and the associated services to connect computer systems

LO4 Demonstrate diagnostic and troubleshooting skills to solve hardware, software and networking related issues.

Essential Content

LO1 **Explain the relationships between hardware components and the subsystems used in a computer system**

Hardware components and subsystems:

Computers consist of four main subsystems (Von Neumann Architecture, Memory, CPU (Arithmetical & Logic Unit (ALU) and Control Unit), Input and output Systems)

Review Memory subsystems regarding programs and data (variable) storage (ROM, RAM, size, speed, operation and structure)

Explore Input/output systems and structure (communicating with other devices (screen, keyboard, printers, etc.), storage (Hard Disk Drives (HDD), DVD's, etc.), IO controllers & data transfer (speed, buffers, interrupts, etc.)

Discuss ALU subsystems (mathematical & logical operations, registers, bus, etc)

Investigate how the Control Unit works (program code & language, fetch, decode, execute, halt) including an introduction to machine language instructions (reduced instruction and complex instruction sets: arithmetic, compare, branch, control, Program Counter (PC), Instruction Register (IR) and Instruction decoder.

LO2 **Categorise the key features and services provided by different computer operating systems and hardware**

Operating system types and hardware:

Introduce different operating systems and types (desktop & server/network, mobile, embedded systems (e.g. Windows 10, Windows Server 2012/2016, Linux, Unix, MacOS, IOS, Android, etc)

Hardware management and connections including the hardware abstraction layer, firmware and device drivers (network cards, video cards, optical drives, magnetic disks, solid state drives, RAID, etc)

Installing and configuring common peripheral devices (mouse, keyboard, scanners, biometrics, webcams, smartcards, motion sensor, printers, speakers, display devices, etc.).

Features and services:

Introduce Operating Systems Architecture (Kernel, File Systems, API)

Review how operating systems function and provide services (user interface, memory management (Direct Memory Access), file management).

LO3 **Use network communication technology and the associated services to connect computer systems**

Networking technology and services:

Introduction to network protocols (HTTP, SMTP, TCP, UDP, etc.) including the OSI and TCP/IP models

Hardware and network addresses (physical/MAC addresses, logical/IP addresses)

Network devices and components (network interface cards (NIC), network cables, switches, wireless access points, routers, network services).

Connecting computer systems to a network:

Introduce topologies including physical and logical: bus, star (extended star), ring and mesh

Establishing network connections including wired/wireless client configuration

Security of networking systems and the importance of this.

LO4 **Demonstrate diagnostic and troubleshooting skills to solve hardware, software and networking related issues.**

Hardware, software & networking issues and maintenance:

Different hardware and software related problems and the implication of choices with regards to system administration, impact on users and business operations.

Explore methods of maintenance with regard to hardware and software. Diagnostic and troubleshooting skills:

Discuss information gathering methods and techniques (such as: system documents, user information, error codes, error messages, failure domain, problem history, etc.)

Consider solutions to security problems.

Analyse evidence and establish possible problem domains, complexity, priority and impact; introduce 'Research, Determine, Implement, Review, Document (and Repeat)'

Creating and updating system documentation.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explain the relationships between hardware components and the subsystems used in a computer system</td><td rowspan="4">LO1 and LO2

D1 Evaluate the structure and functions of an operating system including memory, processor, device, file, security, performance and error management with regards to functionality, operation and dependency.</td></tr>
<tr><td>P1 Identify the main subsystems of a computer and explain how they are organised and connected.

P2 Explain the purpose of the Central Processing Unit (CPU) and include details on its operation.</td><td>M1 Review the operation of the CPU and assess its dependency and performance with regards to associated systems and subsystems.</td></tr>
<tr><td colspan="2">LO2 Categorise the key features and services provided by different computer operating systems and hardware</td></tr>
<tr><td>P3 Describe a range of different operating systems including the purpose, use and hardware requirements of each.

P4 Discuss the key features associated with the architecture of an operating system.</td><td>M2 Analyse the services provided by an operating system with regards to user interaction, memory management, file management and hardware support.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Use network communication technology and the associated services to connect computer systems		
P5 Explain the relationships between hardware and network addresses including their use with regards to networking devices and components. **P6** Setup, configure and document appropriate hardware and software systems to establish computer based network connectivity.	**M3** Compare common physical and logical networking topologies and explain the differences and purposes of each.	**D2** Evaluate the OSI and TCP/IP models with regards to hierarchy, layers and services including information on the associated protocols and hardware.
LO4 Demonstrate diagnostic and troubleshooting skills to solve hardware, software and networking related issues.		
P7 Use information gathering methods to assess, troubleshoot and document solutions to a number of different technical hardware, software and networking issues. **P8** Conduct and document a range of maintenance activities with regards to computer hardware and software.	**M4** Review different diagnostic and troubleshooting skills including data gathering methods and techniques.	**D3** Assess any future improvements that may be required to ensure the continued effectiveness of a computer system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Docter, Q., Dulaney, E. and Skandier, T. (2015) *CompTIA A+ Complete Study Guide: Exams 220-901 and 220-902.* New York: John Wiley & Sons Inc.

Mueller, S. (2015) *Upgrading and Repairing PCs.* New York: Que Publishing.

Patterson, D. and Hennessy, J. (2013) *Computer Organization and Design: The Hardware/Software Interface*. New Jersey: Elsevier.

Links

This unit links to the following related units:

Unit 4056: Programming

Unit 4057: Networking

Unit 4058: Strategic Information Systems.

Unit 4060: Surveying, Measuring and Setting Out

Unit code H/615/1393

Unit level 4

Credit value 15

Introduction

Infrastructure and new buildings are essential requirements of modern life. In both construction and civil engineering there is a need to conduct initial surveys to assist the design team in establishing a clearly defined starting point. Once designed, the priority becomes to 'set out' the structures to the required accuracy to facilitate the construction process. Finally, 'as built' surveys are necessary to assist future maintenance and improvements to the built asset.

This unit explores the techniques used to set up controls and conduct topographic surveys. It also covers communication of results and methods of setting out structures.

On successful completion of this unit students will be able to set up and assess the accuracy of control points. From these or any other control points the students will be able to complete a topographic survey or set out a structure. The students will also be able analyse errors in setting out and surveying.

*This unit is the same unit as *Unit 7: Surveying, Measuring & Setting Out* in the *Pearson BTEC Higher Nationals in Construction*

Learning Outcomes

By the end of this unit students will be able to:

LO1 Undertake a survey to establish a station network for horizontal and vertical control

LO2 Explain the process of undertaking a topographic survey

LO3 Apply industry standard techniques in the production, transferring and staking out of co-ordinates of multiple construction elements

LO4 Prepare a report on the causes of errors and techniques to improve accuracy, including the use of digital data.

Essential Content

LO1 **Undertake a survey to establish a station network for horizontal and vertical control**

Description of types of control points

Primary controls, first and second order

Secondary control

Different methods of marking control points

The use of local, national and grid control available

Conducting a closed traverse

Carrying out a full closed traverse survey for horizontal and vertical controls

Methods for checking accuracy of the traverse

Matching the control station accuracy to national standards or recommendations

Calculations to obtain corrected co-ordinates.

LO2 **Explain the process of undertaking a topographic survey**

Purpose of a topographic survey

Links to initial control

Techniques to communicate a completed survey

Cut and fill information obtained from a survey

Methods of completing a topographic survey

Equipment to be used to capture topographic details

Use of free station and GPS to complete the survey

Coding systems for features to be surveyed

Data transfer techniques.

LO3 **Apply industry standard techniques in the production, transferring and staking out of co-ordinates of multiple construction elements**

Examples of construction elements.

Building outlines, centre lines of structural elements, boundary locations from national co-ordinates, road centre lines, drainage and hard landscape features.

Setting out techniques.

Holistic view of setting from the whole to the part

Use of free station, reference lines, stake out, tie distances within a total station program

Techniques to obtain setting out data, including data transfer

Process of setting out structures and offsetting lines of structural elements

Horizontal and vertical control of construction, both initially and as the work commences.

LO4 **Prepare a report on the causes of errors and techniques to improve accuracy, including the use of digital data.**

Errors in surveying and setting out.

Instrumentation error: prism constants, reflector heights, atmospheric influences, calibration certification, free station errors, discrete setting out

Human errors: alignment of levelling staffs and hand- or tripod-mounted prisms, physical setting out constraints.

Improvement of accuracy:

Use of technology to provide checking methods

Testing procedures for instrumentation to be used in setting out and surveying

Comparing accuracy of set out element to nationally recognised standards.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Undertake a survey to establish a station network for horizontal and vertical control		**LO1 and LO2**
P1 Describe the types of control networks that are available for surveying, including examples of local and national stations. **P2** Carry-out a closed traverse survey of a network, including at least five stations. **P3** Calculate corrected co-ordinates and heights for the stations and explain the stages used.	**M1** Calculate and compare the accuracy achieved in a closed traverse survey.	**D1** Assess the accuracy of a network in the production of a topographic survey.
LO2 Explain the process of undertaking a topographic survey		
P4 Explain the process of conducting a topographic survey for a given plot of land, including initial control. **P5** Describe, with examples, common coding systems and data exchange processes, including communicating final outcomes.	**M2** Review the content of a topographic survey, including analysis of its suitability to assist the design team in completing the design.	

Pass	Merit	Distinction
LO3 Apply industry standard techniques in the production, transferring and staking out of co-ordinates of multiple construction elements		
P6 Extract and transfer the required data from a given project to a total station in order to allow setting out to commence. **P7** Complete a full setting out operation on a given project by utilising a total station free station programme, including both horizontal and vertical control.	**M3** Analyse the accuracy achieved from a setting out operation from tie distances recorded, total station stored data and another means.	**D2** Analyse both the accuracy achieved and the techniques used during the practical exercise.
LO4 Prepare a report on the causes of errors and techniques to improve accuracy, including the use of digital data.		
P8 Prepare a report on the common causes of errors in both setting out and surveying. **P9** Compare the accuracy of setting out data to national standards.	**M4** Evaluate the causes of errors in surveying, setting out and data transfer.	**D3** Analyse the techniques used to improve accuracy, including the implication of setting out errors and the application of industry standard technology/ software.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Irvine, W. and MaClennan, F. (2005) *Surveying for Construction*. 5th Ed.
London: McGraw-Hill.

Schofield, W. and Breach, M. (2007) *Engineering Surveying*. 6th Ed.
Oxford: Elsevier.

Sadgrove, B.M. (2007) *Setting Out Procedures for the Modern Built Environment*.
London: Ciria.

Uren, J. and Price, W. (2010) *Surveying for Engineers*. 5th Ed.
Basingstoke: Palgrave Macmillan.

Websites

ice.org.uk	Institution of Civil Engineers (General reference)
tsa-uk.org.uk	The Survey Association (General reference)

Links

This unit links to the following related units:

Unit 4048: Track Design

Unit 4072: Construction Technology.

Unit 4061: Programming for Engineers

Unit Code: A/650/2923

Level: 4

Credits: 15

Introduction

With the increasing programmability of devices, it is essential that engineers can define and develop software artefacts. Engineers are often involved in developing programs for a wide variety of projects, such as creating firmware, automating robots and machines, modelling conceptual designs, processing data, and developing machine-learning models. By acquiring programming competencies, engineers can meet these challenges, reap the benefits of customised designs, and develop solutions to solve future engineering problems, thus enhancing their career prospects.

This unit provides engineering students with a comprehensive introduction to programming. Students will be able to investigate different software development platforms, programming paradigms, programming languages (e.g. Python, C or C++), and their engineering applications. They will gain the experience of going through a standard development process; from setting requirements through to design, implementation, testing and maintenance. The unit also covers program design, structure, and syntax through project activities. Students will be assessed on creating programs that are efficient, functional, reliable, and maintainable.

On completion of this unit, students will have acquired essential knowledge and skills in programming using a popular language that can be utilised in Level 5 units such as Machine Learning and Embedded Systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Discuss key aspects of software evolution and development in the context of engineering applications

LO2 Design a programming solution for an engineering problem

LO3 Implement a programming solution for an engineering problem

LO4 Perform testing of the programming solution to meet defined requirements and to ensure high-quality outputs.

Essential Content

LO1 Discuss key aspects of software evolution and development in the context of engineering applications

Programming in engineering:

Evolution of programming concepts; paradigms (e.g. object-oriented, event-driven, procedural, functional); development platforms including IDEs; current/future trends

Processes/components of programming environment (i.e. microcomputer hardware: CPU, arithmetic logic unit (ALU), registers, memory; fetch-execute cycles)

Devices/systems that can be programmed (e.g. computers, mobile phones, tablets, industrial controllers, field-programmable gate arrays (FPGAs))

Programming languages and platforms with which to program devices/systems (e.g. Python, C, C++, C#, ADA, Java and MATLAB); comparisons (e.g. compiled versus interpreted languages).

Engineering applications and practical skills:

Project-based learning (PBL) approach for understanding planning, development and delivery of small/medium-sized engineering applications

Software engineering principles, software development life cycle, methodologies (e.g. agile, waterfall), roles and responsibilities of a development team (e.g. analyst, programmer, tester, Scrum master, product owner), modelling and prototyping. Overview of Engineering project management techniques for programmers (e.g. SWOT, stakeholder matrices, risk mapping, radar chart and summary risk profiles).

Edit, execute and test example engineering applications

Developer attributes: responsibility towards planning and prioritisation of development activities in meeting business needs, ability to work independently, pro-active, initiative, communicative, keen to analyse root cause of problems, contextual knowledge and skills for practice, solve and develop efficient and ethical solutions

Programming case studies:

Embedded systems, automation, Industry 4.0, machine learning (AI), networking, Internet of Things (e.g. smart factories), cloud computing, cybersecurity; concepts, purpose and application

Industry relevance (e.g. manufacturing, defence, medical, automotive, aeronautics, space technologies, utilities, consumer goods)

Occupation-centric: programming tools for diagnostics (e.g. web-based diagnostics for network devices and other software tools such as PROFITrace), interconnected occupational competencies (e.g. network engineers to bring together programming skills and network installation and management skills to solve problems).

Best practices:

Coding standards, secure programming, green coding, programmer ethics, accessibility.

LO2 Design a programming solution for an engineering problem

Program design, structure and maintenance:

Requirements analysis and specification, flow and function charts, pseudocode, selection and application of design methodology, design for testing and maintenance, occupational role and relevance in designing maintainable software solutions (e.g. use of software tools/techniques for troubleshooting network issues, securely isolate and debug faults, automate different aspects of network maintenance)

Documentation of design (e.g. project name, description, version control such as Git and commentary); reading, extracting and interpreting technical, business related and other relevant documentation.

Programming features:

Data types and operators (i.e. integers, floating point, strings, characters, Boolean, arithmetic, relational, logical, bitwise, assignment)

Data type qualifiers (e.g. mutable and immutable)

Classes and object-oriented programming (OOP) concepts (i.e. abstraction, polymorphism, encapsulation, inheritance)

Data structures (i.e. arrays, lists, sets)

Control structures (i.e. decision, selection, and iterative statements)

Input/output (i.e. file reading and writing, standard I/O, databases)

Libraries (i.e. GUI, networking, logging)

Data management: cleaning data, producing statistical analysis of data.

Algorithmic design and development:

Example algorithms for engineering problems (e.g., path finding)

Design algorithms for a range of small engineering applications

Complexity analysis, Big-O notation.

LO3 Implement a programming solution for an engineering problem

Benefits of modular design:

Development efficiency, maintainability, testability, reusability and debugging.

Declaring, defining and calling functions:

Naming, return type and arguments (parameters), function body

Passing data to and receiving data from functions, call functions by value, and call by reference

Life cycle of variables in functions (e.g. global versus local, class versus instance)

Recursive functions.

Preprocessor directives:

Include, import statements, C header files, macro definitions, sharing between multiple source files, #define, #ifndef statements

Python packages.

Program development and implementation:

Develop and implement small engineering applications using a suitable programming language; develop documentation to industry standards and style guides

Explore team approach to program development and delivery

Consider possible user-experience concerns and how these could be solved.

LO4 Perform testing of the programming solution to meet defined requirements and to ensure high-quality outputs

Overview of testing:

Software testing frameworks and methodologies including functional (e.g. unit testing, integration, system, acceptance) and non-functional (e.g. usability, performance, security, compatibility) methods; tools and techniques to monitor and enhance performance against requirements

Test environments

Continuous integration/continuous development (CI/CD) pipeline and continuous testing.

Approach to testing:

Relationship between test activities and program development activities; identify elements that need to be tested; consider data that should be used to fully test the program; match tests against the defined requirements (e.g. user, system); use of test harnesses

Use of relevant test procedures: test plans, test techniques (e.g. open-box, closed-box); testing documentation (e.g. reports, plans, checklists)

Overview of alpha and beta testing.

Debugging:

Use of debugger tools; documentation of the debugging process with reference to watch lists, breakpoints, and tracing

Debugging the process to fix vulnerabilities, defects and bugs in code

Understand coding standards and their benefits when writing program code in a team as well as for the individual.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Discuss key aspects of software evolution and development in the context of engineering applications</td><td rowspan="2">D1 Evaluate industry-recognised best practices in using software life-cycle models for engineering problems.</td></tr>
<tr><td>P1 Discuss the key stages of the software development life cycle, including the roles and responsibilities of team members

P2 Present a choice of programming languages and development platforms for a given engineering problem.</td><td>M1 Analyse the suitability of any two specific software life-cycle models for a given engineering problem.</td></tr>
<tr><td colspan="2">LO2 Design a programming solution for an engineering problem</td><td rowspan="5">LO2, LO3 and LO4

D2 Reflect on the design, implementation, testing and documentation aspects of engineering programming solutions, including use of coding standards and why it is necessary in a team as well as for the individual.</td></tr>
<tr><td>P3 Produce an outline requirements specification for a given engineering application

P4 Design a suitable algorithmic solution for the key requirements.</td><td>M2 Refine the requirements specification and a suitable design solution to cover the full set of requirements, including modularity and maintainability.</td></tr>
<tr><td colspan="2">LO3 Implement a programming solution for an engineering problem</td></tr>
<tr><td>P5 Implement a given design solution for an engineering problem using an appropriate programming language

P6 Demonstrate successful execution of the developed solution in a chosen programming environment.</td><td>M3 Refine the implemented solution for modularity and maintainability.</td></tr>
</table>

Pass	Merit	Distinction
LO4 Perform testing of the programming solution to meet defined requirements and to ensure high-quality outputs.		
P7 Produce a test plan to demonstrate whether the program meets the key requirements **P8** Perform tests on the program against the key requirements, resolving any functional errors.	**M4** Analyse the effectiveness of testing, including an explanation of the choice of tests used **M5** Demonstrate the use of debugging tools to identify and correct errors in a programming solution	

Recommended Resources

This unit does not specify which programme language should be used to deliver this content – this decision can be made by the academic staff.

Examples of languages that are used in industry are Python, C, C++, C#, ADA, Java, and MATLAB but any language which will allow the student to achieve the Learning Outcomes is acceptable.

Note: See HN Global for guidance on additional resources.

Print Resources

Bradley R. (2011) *Programming for Engineers: A Foundational Approach to Learning C and MATLAB*. Springer.

Clough D.E. and Chapra S.C. (2023) *Spreadsheet Problem Solving and Programming for Engineers and Scientists (Hardback).* Taylor & Francis Ltd.

Cyganek B. (2020) *Introduction to Programming with C++ for Engineers*. Wiley/IEEE Press.

Kenan A. (2020) *Python for Mechanical & Aerospace Engineering*.

Nagar S. (2017) *Introduction to Python for Engineers and Scientists*. Apress.

Sanchez J. and Canton M.P. (2017) *Java Programming for Engineers (Hardback).* Taylor & Francis Ltd.

Sierra K., Bates B. and Gee T. (2022) *Head First Java.* 3rd Ed. O'Reilly Media.

Sola A. (2021) *Hardcore Programming For Mechanical Engineers: Build Engineering Applications from Scratch (Paperback).* No Starch Press,US.

Wei-Bing J., Aizenman H., Espinel E.M.C., Gunnerson K. and Liu J. (2022) *An Introduction to Python Programming for Scientists and Engineers (Paperback).* Cambridge University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advances in Engineering Software

Computer Applications in Engineering Education

Journal of Computer Science and Control Systems

Programming Journal.

Links

This unit links to the following related units:

Unit 5013: Embedded Systems

Unit 5047: Computer Architecture and Interfacing

Unit 5050: Machine Learning Systems and Programming.

Unit 4062: Professional Engineering Practice

Unit Code: **M/651/0803**

Level: **4**

Credits: **15**

Introduction

The work of the engineer is key to the development and progress of our society. The decisions they make in the course of their everyday work can be life-changing in positive ways or, if poorly made, can be life-threatening. Accordingly, the engineer must work to strict codes of professionalism in all aspects of their work.

This unit outlines the background to the legislation, professional codes of practice and operational competencies that underpin the development of the professional engineer. It also considers the roles of problem-solving, communication, team working and professional responsibility.

Elements of personal and professional development, reflective thinking, career planning and leadership are considered as well. The increasing necessity for a holistic approach to sustainability in design, manufacture, and reuse and recycling are emphasised.

On successful completion of this unit, the student will be well prepared for further study at levels 5 and 6, working towards membership of an appropriate professional institution at Incorporated Engineer level.

Learning Outcomes

By the end of this unit the student will be able to:

LO1 Determine the roles, responsibilities and competences of the professional engineer

LO2 Describe the regulatory, legislative and ethical frameworks that govern the work of the professional engineer

LO3 Review the roles of communication, team working and leadership in the development of professional engineers

LO4 Discuss how professional engineers can develop holistic approaches to the sustainability of manufacturing processes.

Essential Content

LO1 Determine the roles, responsibilities and competences of the professional engineer

Role of the professional engineer:

Transforming ideas and materials into products and services: design, build, test and improve; consideration of the whole life cycle of the output of the engineer's work, including sustainability and end-of-life provision of recycling and reuse.

Responsibilities:

The importance of proper risk identification, assessment and mitigation; appropriate safety factors; examples of discipline-specific failures due to poor engineering/lack of proper 'what if' procedures

Understanding that human factors affect engineering processes

Adherence to codes of conduct; acting with due care, skill and diligence by recognising appropriate behaviours and possible limitations; preventing avoidable dangers/adverse impact on the environment; enhancing operational competence

The importance of considering the effects of certain behaviours and values: attitude, persuasion, coercion, rapport, authority

Effects of external influences: stress, time pressure, fatigue, memory, capability, motivation, knowledge, experience, health, alcohol, drugs and criminal behaviour

Personal and corporate privacy and security.

Competences:

Digital skills and industrial digitalisation technologies (IDTs); research skills − find, extract, organise, analyse, evaluate and use or present relevant information; project planning and management (i.e., change management, compliance in delivering outputs, responsible planning and work prioritisation, predictive maintenance); financial literacy (e.g.
financial planning, data, reporting); individual and team approaches to solving problems and risk management through use of methods such as Fishbone, practical problem solving (PPS), root cause analysis (RCA), advanced Product Quality Planning (APQP) and process failure mode effects analysis (PFMEA); project management techniques (e.g. SWOT, stakeholder matrices, risk mapping, radar chart and summary risk profiles), time management, organisation and record-keeping; sketching, drawing, use and interpretation of computer-aided design (CAD)

Professional engineering capabilities: installation, commissioning, shut-down, start-up and maintenance/service/support of a wide range of systems and devices; use of relevant manufacturing and production methods; ability to follow and apply latest trends in engineering and manufacturing (e.g., lean methods and tools used in manufacturing and engineering such as Kaizen, Six Sigma, 8 wastes, 5S's and Poka-Yoke), commitment to upskilling/reskilling, and continued professional development.

Reflective practice: cycle of reflection in action and on action, refining ongoing professional practice (future behaviour), setting goals, reviewing again to achieve sustainable performance; evaluation of own and others' work

Avoidance of generalisation; focus on personal development in a critical and objective way.

LO2 **Describe the regulatory, legislative and ethical frameworks that govern the work of the professional engineer**

Regulatory and legislative frameworks:

Global, European and national regulatory influences on engineering and the role/occupation of the engineer (e.g. the Royal Academy of Engineering and the Engineering Council in the UK); role and responsibilities of the Engineering Council and professional engineering institutions (PEIs), UK Standard for Professional Engineering Competence (UKSPEC), or international equivalents

Relevant health and safety standards, codes and regulations; principles of functional machinery and/or process safety, including SIL (safety integrated level) and PL (performance level) terminology; appropriate sector legislation for quality control/assurance and management (e.g. electrical safety system legislation and directives, emissions, construction and use, environmental legislation, UN Sustainable Development Goals, British Standards Institution (BSI) and International Organization for Standardization (ISO) standards e.g. ISO 14090: 2019 Adaptation to climate change)

Responsibilities at various levels of engineering (e.g. Engineering Council Technical, Incorporated and Chartered Engineer professional registration levels, or international equivalent) including secure operations and application of appropriate processes, policies and legislation in the context of business goals, vision and values; responsible selection of tools/techniques in upgrading and maintaining systems; resilience in undertaking tasks and working securely within the business.

Ethical frameworks:

The Engineering Council and The Royal Academy of Engineering's Statement of Ethical Principles; The National Society for Professional Engineers' Code of Ethics.

LO3 **Review the roles of communication, team working and leadership in the development of professional engineers**

Communication:

Listening, non-verbal communication, clarity and brevity, friendliness, role of humour; confidence, empathy, open-mindedness, respect, feedback and picking the right medium for presentations

Presentation skills, use of presentation software, summaries and presentation notes.

Team working:

Group expectations, dealing with reactions and disagreements, allowing and encouraging participation, acting on agreed outcomes; the negative effects of communication without cause; disillusioned colleagues, persuasion and negotiation

Rewarding and motivating; peer assessment of work, mentoring at regular intervals to ensure correct working practices, getting and receiving feedback

Ensuring inclusivity and equality of opportunity; respecting and encouraging diversity; avoiding stereotyping.

Leadership:

The role of the leader; vision, responsibility and accountability

Decision-making, creative problem-solving, adaptability, delegation, trust and confidentiality

Setting expectations and goals; effective stakeholder engagement and managing job roles and responsibilities; developing accessible, inclusive and diverse products and workplace culture; strategic resource allocation and prioritisation; managing performance and encouraging development.

LO4 **Discuss how professional engineers can develop holistic approaches to the sustainability of manufacturing processes**

Design optimisation:

Overview of manufacturing methods for design of products, Design for Manufacture (DFM), Design for Assembly (DFA) and Design for Disassembly (DFD) as more holistic optimisations of product design to reduce complexity; simplification of assembly and finishing processes by design; quality assurance by design to ensure operation, consistency and quantification of enhancement of manufacturing and process applications

Concepts of the perfect design cycle, product stewardship, dematerialisation, modularity, longevity and design for disassembly

Recyclability, repairability, reusability, re-manufacture; efficiency of active products (e.g. light bulbs, washing machines or vehicles)

Advancements in design for Industry 4.0.

Environmental legislation:

Response to legislative change (e.g. termination of petrol and diesel vehicle production); consideration of diminishing supply of essential raw materials (e.g. oil, aluminium ore and rare earth elements) and development of man-made substitutes, to include cost, supply and political considerations.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine the roles, responsibilities and competences of the professional engineer		
P1 Describe the importance of the identification of risk in the role of the professional engineer. **P2** Determine how responsibilities and human behaviour can impinge on the work of professional engineers.	**M1** Assess the risk factors that require mitigation from a given engineering project specification.	**D1** Differentiate between reflection and evaluation with risk factor examples, using a given engineering project specification, and your own experience.
LO2 Describe the regulatory, legislative and ethical frameworks that govern the work of the professional engineer		
P3 Outline the roles and responsibilities of the professional engineer (IEng) within the Engineering Councils framework (or international equivalent). **P4** Describe the principal UK codes and regulations, (or international equivalents) that control the work of the professional engineer.	**M2** Analyse how engineers use regulatory and legislative frameworks and how the UN Sustainable Development Goals should be considered within a given design specification.	**D2** Evaluate the effect of regulatory, legislative and ethical frameworks on the day-to-day work of the professional engineer, using specific examples.

Pass	Merit	Distinction
LO3 Review the roles of communication, team working and leadership in the development of professional engineers		
P5 Review the most important considerations for good team working and effective leadership in engineering. **P6** Outline the steps for managing effective group communications in engineering.	**M3** Analyse leadership styles and effective communication skills using specific examples from an engineering organisational context.	**D3** Evaluate the most effective approaches to the coaching and mentoring of disillusioned colleagues or of a poorly performing team.
LO4 Discuss how professional engineers can develop holistic approaches to the sustainability of manufacturing processes.		
P7 Discuss the rationale behind the development of Design for Manufacture (DFM) and Design for Assembly (DFA) methodologies. **P8** Describe the concept of the Perfect Design Cycle and show how it incorporates Product Stewardship.	**M4** Assess the effects that fully committing to sustainable design and manufacture would have for a given design specification.	**D4** Analyse how the drive for sustainability can be sustained given the limitations on naturally occurring materials such as oil, aluminium ore and rare earth elements.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bainbridge A.F. (2021) *Ethics for Engineers: A Brief Introduction*. 1st Ed. Oxfordshire: Taylor & Francis Ltd.

Challender J. (2022) *Professional Ethics in Construction and Engineering*. Wiley.

Covello V.T. (2021) *Communicating in Risk, Crisis, and High Stress Situations: Evidence-Based Strategies and Practice*. Wiley.

Dearden, H. (2013) *Professional Engineering Practice: Reflections on the Role of the Professional Engineer*. CreateSpace Independent Publishing Platform.

El-Reedy M.A. (2021) Offshore Projects and Engineering Management. 1st Ed. Elsevier.

Karten N. (2010) *Presentation Skills for Technical Professionals*. IT Governance Ltd.

Kerzner H. (2022) *Project Management: A Systems Approach to Planning, Scheduling, and Controlling.* 13th Edition, Wiley.

Kong K. (2019) *Professional Discourse.* Cambridge University Press.

Lock D. (2013) *Project Management*. 10th Ed. Routledge.

McRae M and Berliner J (2020) *Engineering Made Simple: A Complete Guide in Ten Easy Lessons.* 1st Ed. San Diego: Portable Press.

Muzio D., Sundeep A. and Kirkpatrick I. (2020) *Professional Occupations and Organizations.* Cambridge University Press.

Rausand M. and Stein Haugen S. (2020) *Risk Assessment: Theory, Methods, and Applications.* John Wiley & Sons, Inc.

Temple T.J. and Ladyman M.K. (2022) *Challenges in Risk Analysis for Science and Engineering*. IOP Publishing Ltd.

Wilbers S. (2022) *Persuasive Communication for Science and Technology Leaders: Writing and Speaking with Confidence*. Wiley.

Wright I. (2012) *Risk Evaluation (Engineering Design Book 1)*. Kindle Edition.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Control Engineering Practice

Engineering

Engineering Management

Engineering Management Journal

European Journal of Engineering Education

Frontiers of Engineering Management

IEEE Transactions on Engineering Management

Journal of Engineering and Technology Management

Journal of Management & Organization

Journal of Professional Issues in Engineering Education and Practice

Results in Engineering

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4031: Introduction to Professional Engineering Management

Unit 5002: Professional Engineering Management

Unit 5041: Engineering Project.

Unit 4063: Engineering Mechanics and Materials

Unit Code: F/650/2943

Level: 4

Credits: 15

Introduction

Every aspect of engineering depends upon the use and manipulation of materials. Whether naturally occurring or man-made, it is the properties of these materials that are fundamental to their creation, processing and application.

This unit explores the fundamental structure of common engineering materials, their principal mechanical, chemical and electrical properties, and how these properties affect manufacture, application, service life and end-of-life management and recycling. Systems for categorising and ranking materials are also covered.

Finally, the service life performance of these materials is studied through calculations that measure their performance in static and dynamic applications, building on the work started in the associated level 4 unit, Engineering Science.

On successful completion of this unit, students will be able to identify the underlying structural properties of engineering materials and how these properties relate to their application and performance. They will also be confident in completing calculations relating to the static performance of these materials when in service.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Describe the fundamental structures of common engineering materials

LO2 Determine the most important properties of engineering materials

LO3 Assess the performance of engineering materials using key indicators, including materials constraints and established database resources

LO4 Calculate solutions to problems within static and dynamic mechanical systems, with consideration of constraints on performance.

Essential Content

LO1 Describe the fundamental structures of common engineering materials

Classification of materials:

Metals, polymers, ceramics, composites, semiconductors, biomaterials, smart and nano materials; sub-classification of important materials, for example, ferrous and non-ferrous metals, alloys, thermoplastic and thermosetting polymers.

Structure of materials:

Atomic and molecular bonding; bonding forces; primary atomic bonding; ionic, covalent, hybridisation and metallic bonding

Secondary bonding, van der Waals forces, dipole bonds; mixed bonding and bonding energies

Crystallography of materials, unit cells, crystal systems, cubic and hexagonal; single crystal and polycrystalline materials; defects, dislocations, slip planes and impurities; polymorphism and allotropy, introduction to phase diagrams; non-crystalline (amorphous) materials

Structure and application of specific common materials, including metals, polymers and ceramics; changes to structure and properties due to alloying, doping, heat treatment and processing.

LO2 Determine the most important properties of engineering materials

Types of properties:

Mechanical, electrical, chemical, thermal, magnetic, optical and deteriorative (decay); examples of the importance of listed properties and common values; reasons for variation in a material's properties, for example, processing, heat treatment, operating environment

The importance of these properties in design and operation.

Properties of engineering materials:

Definitions, units, applicability and expected values for common material, for example, density, modulus of elasticity, Poisson's ratio, yield and tensile strength, percentage elongation, strength and fracture toughness, coefficient of thermal expansion and thermal conductivity, specific heat capacity and electrical resistivity; appreciation of quantitative and qualitative aspects of the properties of engineering materials

Examples of the importance of listed properties and common values; use of commercial material properties databases to find these values.

LO3 Assess the performance of engineering materials using key indicators, including materials constraints and established database resources

Links between materials properties and structural design:

Design constraints; operating conditions – temperature, loading and environment; cost, availability, processability, appearance and environmental constraints.

Materials selection and the design process:

Analysing the requirements, converting customer's request into a list of constraints for materials selection, creating materials specification parameters; forms of supply of common materials, stock items and special order; research using databases and online sources (e.g. Ansys Granta Selector, Matmatch, Cambridge Engineering Selector, suppliers' catalogues); suggest possible solutions; market analysis (availability, cost and type of supply form); impact on manufacturing/production methods (e.g. single, batch, flow and mass), test and evaluate selection against specification parameters using simulation software; sustainability, end of life and recycling considerations

Report preparation, presentation, feedback, evaluation and modification.

LO4 Calculate solutions to problems within static and dynamic mechanical systems, with consideration of constraints on performance.

Shafts and beams:

Revision of basics, Newton's second law, static equilibrium, types of beams and supports, shear force and bending moment calculations; bending in beams, engineers' theory of bending; selection of appropriate beams and columns to meet given specifications.

Torsion:

Revision of shear stress and strain; theory of torsion in solid and hollow circular shafts, engineers' theory of torsion, power transmitted by a shaft; composite shafts.

Introduction to dynamics:

Revision of conservation of energy and work-energy transfer in engineering systems; linear velocity, angular velocity and acceleration; velocity and acceleration diagrams of planar mechanisms; introduction to gyroscopic motion.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the fundamental structures of common engineering materials		
P1 Describe the crystalline structures of the three most common unit cells found in metals and link these cell types to the metals' engineering properties. **P2** Discuss the different material associated with amorphous and crystalline polymer structures.	**M1** Detail the differences between the effects of impurities, alloying elements and doping processes on the properties of an engineering material.	**D1** Differentiate between polymorphism and allotropy, specifying how the allotropy of iron is employed in the heat treatment of steel to alter its engineering properties.
LO2 Determine the most important properties of engineering materials		
P3 Determine the most important properties, for a given application, of engineering materials. **P4** Explain why the correct assessment of a materials' in-service behaviour is considered so important when selecting a material for a particular application.	**M2** Describe how the properties of metals can be modified by their production processes and how these effects can be subsequently relieved.	**D2** Evaluate Poisson's ratio and Young's modulus to explain their significance in material selection for a specific application.

Pass	Merit	Distinction
LO3 Assess the performance of engineering materials using key indicators, including materials constraints and established database resources		
P5 Use a commercial database to establish values for given material properties. **P6** Assess suitable materials for given products, specifying the normal form of supply for your suggestions.	**M3** Prepare a customer report for a fully costed application using a commercial database, offering at least two alternatives for consideration.	**D3** Explore how metals and polymers are currently recycled and arrangements for end-of-life decisions are made for manufactured products.
LO4 Calculate solutions to problems within static and dynamic mechanical systems, with consideration of constraints on performance.		
P7 Calculate the shear force, bending moment and stress due to bending in given examples of simply supported beams. **P8** Carry out selection exercises for given beams and columns.	**M4** Construct diagrams to find the vector solutions of velocities and accelerations within planar mechanisms.	**D4** Discuss the relationship between the various forms of mechanical energy and their conservation.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby M.F. and Jones D.R.H. (2012) *Engineering Materials 2*. 4th Ed. Butterworth-Heinemann.

Ashby M.F. and Jones D.R.H. (2018) *Engineering Materials 1*. 5th Ed. Butterworth-Heinemann.

Callister W.D. and RETHWISCH D.G. (2020) *Materials Science and Engineering*. 10th Ed. Wiley.

Chehade F.H., Hu C. and Wang K. (Editors) (2022) *Applied Mechanics and Engineering − Applied Mechanics and Materials (Paperback).* Trans Tech Publications Ltd.

Hertzberg R.W., Vinci R.P. and Hertzberg J.L. (2021) *Deformation and Fracture Mechanics of Engineering Materials (Paperback).* John Wiley & Sons Inc.

Hu J.W. (Editor) (2021) *Applied Engineering, Materials and Mechanics IV − Key Engineering Materials (Paperback).* Trans Tech Publications Ltd.

Kalpakjian S. and Schmid S.R. (2013) *Manufacturing Engineering and Technology*. 7th Ed. Pearson.

Mittelstedt C. (2023) *Engineering Mechanics 2: Strength of Materials: An introduction with many examples (Paperback).* Springer Fachmedien Wiesbaden.

Nugroho A.A. and Dahham O.S. (Editors) (2023) *Engineering Materials and Engineering Design − Applied Mechanics and Materials (Paperback).* Trans Tech Publications Ltd.

Tooley M. and Dingle L. (2021) *Engineering Science: For Foundation Degree and Higher National*. 2nd Ed. Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

ACS Applied Engineering Materials

Advanced Engineering Materials

Composites Part B: Engineering

European Journal of Mechanics

International journal of Refractory Metals and Hard Materials

Journal of Engineering Materials and Technology

Journal of Engineering Mechanics

Journal of Engineering Mechanics and Machinery

Journal of Materials Processing Technology

Material Science: Science Direct

Material Science and Engineering

Materials & Design

Materials Testing

Probabilistic Engineering Mechanics

Links

This unit links to the following related units:

Unit 4003: Engineering Science

Unit 4008: Mechanical Principles

Unit 4009: Materials, Properties and Testing

Unit 5003: Advanced Mechanical Principles.

Unit 4064: Analogue and Digital Electronics

Unit Code: H/650/2944

Level: 4

Credits: 15

Introduction

Analogue and digital electronic systems are widely used for a variety of applications. These systems provide the building blocks for modern living; for example, smart devices/homes, Industry 4.0 and autonomous systems. Digital electronics are used to implement circuits such as the microcontroller-based systems found in mobile phones, computers, televisions, microwaves and many other devices. Analogue electronic circuits are commonly used alongside such systems. A smart speaker uses digital systems to perform 'smart' functions and analogue circuits are used to drive the voice interface and speaker response systems. This unit explores some of the specialist applications of these systems.

The overall aim of the unit is to introduce students to the fundamental building blocks of analogue and digital systems. Engineers from the craft technician to the Chartered Engineer should have an understanding and working knowledge of these technologies because they underpin all of our electronic devices, both domestic and industrial. The unit's learning outcomes promote the development of skills and knowledge in the areas of digital and analogue electronics: digital electronics – developing an understanding of the basic logic components and how they are constructed, tested and used in circuit design; analogue electronics – developing an understanding of common transistors and transistor circuit design. Transistor and operational amplifier systems are another focus of the unit; these types of circuits are essential for signal processing and reproduction.

On successful completion of the unit, students will have developed skills and knowledge in analogue and digital electronics, which are the basis of all electronic systems and device, including the understanding and practice of the theory of logic circuits and how to construct and test such systems, and the understanding and measurement of analogue circuits.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Investigate logic functions

LO2 Produce tabular and Karnaugh map designs to implement logic systems

LO3 Examine the use of Class A and Class B amplifiers in modern systems

LO4 Investigate operational amplifier circuits and their application.

Essential Content

LO1 **Investigate logic functions**

Underlying theory:

Logic function implementation: transistor–transistor logic (TTL)

Logic functions: AND, OR, NOT, NAND, NOR and XOR

Complementary metal–oxide–semiconductor (CMOS), emitter-coupled logic (ECL) and current developments

Testing instruments: Pulser, Logic Probe.

Testing digital gates by simulation:

Test logic gates using simulation: AND, OR, NOT, NAND, NOR and XOR

Data sheets and specifications: fan-out, speed, maximum and minimum ratings.

Testing digital gates using TTL and CMOS devices:

Test logic gates in laboratory experiments using TTL and CMOS devices: AND, OR, NOT, NAND, NOR and XOR.

LO2 **Produce tabular and Karnaugh map designs to implement logic systems**

Underlying theory:

Boolean algebra minimisation and reduction techniques

Minimisation using De Morgan's theorems

Minimisation using Karnaugh maps

Minimisation using truth tables.

Logic functions:

Logic functions: AND, OR, NOT and, by extension, NOT AND (NAND), NOT OR (NOR) and Exclusive OR (XOR)

Symbols representation, such as American National Standards Institute (ANSI) and British Standard European Norm (BSEN) Symbols representation using Boolean algebra, Karnaugh maps and truth tables

De Morgan equivalents.

Digital design techniques:

Use of reduction techniques on multivariable circuits, with a maximum of four input variables, to design to a specific requirement: tabular methods, Karnaugh maps, Boolean algebra

Reduction and construction of logic circuits to a given design specification.

LO3 **Examine the use of Class A and Class B amplifiers in modern systems**

Underlying theory:

Input and output impedance of Class A, B and C amplifier circuits using bipolar transistors and metal–oxide–semiconductor field-effect transistors (MOSFETs)

Small-signal and h-parameter models.

Design using bipolar transistors:

Design techniques and requirements of a Class A bipolar transistor amplifier; determine input and output impedance, as well as bandwidth response

Design techniques and requirements of a Class B bipolar transistor amplifier; determine input and output impedance as well as bandwidth response.

Design using MOSFETs:

Design techniques and requirements of a Class A MOSFET amplifier; determine input and output impedance as well as bandwidth response

Design techniques and requirements of a Class B MOSFET amplifier; determine input and output impedance as well as bandwidth response.

LO4 **Investigate operational amplifier circuits and their application.**

Underlying theory:

Operational amplifier design: differential pair, Miller effect, current mirror, long-tailed pair, Class AB amplifier, frequency response, symbol

Operational amplifier parameters: slew rate, offset, common-mode input, gain–bandwidth product, open-loop gain

Use of data sheets to ascertain design data

Negative feedback model; operational amplifier circuit configurations: comparator, summing amplifier, inverting amplifier, non-inverting amplifier, differentiator, integrator, digital-to-analogue converter, oscillators.

Laboratory practice:

Simulate standard circuits using alternating current (AC) signals: comparator, inverting amplifier, non-inverting amplifier, differentiator, integrator

Simulate standard circuits using direct current (DC) signals: comparator, summing amplifier, inverting amplifier, non-inverting amplifier, digital-to-analogue converter (DAC), and analogue-to-digital converters (ADCs): simple-ramp ADC, successive-approximation ADC

Construct trigger circuits using comparator designs for light, and for temperature

Use modern diagnostic tools and equipment including Industry 4.0, cloud-based diagnostics incorporated into network devices and other software tools (e.g., PROFITrace).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate logic functions		
P1 Investigate logic functions; AND, OR, NOT, NAND, NOT and XOR. **P2** Test logic gates by simulation and using TTL and CMOS devices and standard laboratory equipment, and present results.	**M1** Assess device performance in terms of device speed and functionality.	**D1** Analyse results after adapting and testing De Morgan equivalent function against the speed performance of the original device.
LO2 Produce tabular and Karnaugh map designs to implement logic systems		
P3 Produce logic circuits to a given design specification using tabular techniques. **P4** Produce logic circuits to a given design specification using Karnaugh map techniques.	**M2** Analyse non-minimised and equivalent logic circuits to confirm function.	**D2** Evaluate the performance, in terms of speed, cost and manufacturability, of minimised logic circuits to a given design specification.
LO3 Examine the use of Class A and Class B amplifiers in modern systems		
P5 Examine a Class A amplifier operation and functionality. **P6** Examine a Class B amplifier operation and functionality.	**M3** Analyse Class A and Class B amplifiers using small-signal analysis.	**D3** Evaluate amplifier circuits using bipolar and MOSFET devices.
LO4 Investigate operational amplifier circuits and their application.		
P7 Investigate the operation of a standard operational amplifier circuit. **P8** Simulate a standard operational amplifier circuit to a given design specification.	**M4** Analyse the performance of an operational amplifier circuit in terms of bandwidth, input impedance and output impedance.	**D4** Evaluate the performance of an operational amplifier compared to its small-signal model.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Floyd, T.L. (2015) *Digital Fundamentals*. 11th Ed. Pearson.

Horowitz, P. and Hill, W. (2015) *The Art of Electronics*. 3rd Ed. Cambridge University Press.

Malvino, A.P., Bates, D.J. and Hoppe, P.E. (2020) *Electronic Principles.* 8th Ed. McGraw Hill Education.

Storey, N. (2017) *Electronics: A Systems Approach*. 6th Ed. Pearson.

Tokheim, R.L. and Hoppe, P.E. (2021) *Digital Electronics Principles and Applications.* 9th Ed. McGraw Hill.

Websites

digital-library.theiet.org	IET Digital Library 'IET Circuits, Devices and Systems journal' (Research)

Links

This unit links to the following related units:

Unit 4022: Electronic Circuits and Devices

Unit 4067: Digital Devices and Systems

Unit 5014: Analogue Electronic Systems

Unit 5044: Digital Electronic Systems.

Unit 4065: Internet and Network Technologies

Unit Code: J/650/2945

Level: 4

Credits: 15

Introduction

The Internet and the networks that support it have become an essential part of everyday life. The Internet enables trade through e-commerce, provides entertainment and, with the advent of the Internet of Things, pervades the environment in which we live. The internet is a global network of networks, connecting home and business networks via internet service providers (ISPs) to global internet exchanges. The Internet supports access to digital information anytime, anywhere, using many pervasive applications, such as social media, email, audio and video transmission and the World Wide Web. The Internet is so essential that disruptions can cause chaos at a global scale. Organisations rely on having highly skilled network engineers to keep their systems Internet-connected, performant, highly available and secure.

This unit introduces students to the Internet and the underpinning network technologies that support it. It is important that future network engineers understand the evolution of the Internet and its future direction. Using case studies, students should identify best practices involved in the design and implementation of Internet and network technologies to meet user and business requirements. This should include the design of hybrid cloud networking solutions.

Among the topics in this unit are: the evolution of the Internet's fabric, Internet peering arrangements, Internet and wide area network (WAN) connectivity, network devices, network protocols (e.g. TCP/IP, Ethernet), application protocols (e.g. HTTP, Voice over Internet Protocol (VoIP)) and network security considerations.

On successful completion of this unit, students will understand how the Internet evolved to its current state and how it needs to evolve further to meet future requirements, how to specify and design networks to meet the requirements of users, and how to identify and select protocols and infrastructure components that satisfy security requirements. Students will also develop skills in critical thinking, design interpretation and communication.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Discuss the evolution of the Internet, identifying major technological and usage transitions

LO2 Evaluate the suitability of network protocols to meet application requirements, referencing appropriate standards

LO3 Produce network designs that conform to industry best practice to meet customer requirements

LO4 Analyse the security threats faced by computer networks and communicate mitigation strategies.

Essential Content

LO1 Discuss the evolution of the Internet, identifying major technological and usage transitions

Network structure:

End-user connectivity, modems, PSTN, ADSL, 21CN, HTTP, FTTC, DSLAMs, Mobile, 4G, 5G; business connectivity, leased line services; network services and functions, role of ISPs, Internet exchanges, peering points (IXPs), peering data sources (e.g. PeeringDB); academic networks (e.g. the Joint Academic Network (JANET)); role of Tier 1 providers, transit costs. Network infrastructures, causes and consequences of network and IT infrastructure failures.

Policies, standards and regulations:

Importance of standards bodies in ensuring interoperability, IETF, W3C; important standards documents (e.g. RFCs); review standards for commonly used protocols; evolution of Internet regulation and legislation by country, difficulty in enforcement of same.

Evolution of usage:

Origins as ARPANET, ASCII-based (e.g. gopher); WWW, HTML, JavaScript, Flash; WebGL, video streaming, video conferencing; Semantic Web, Web 3.0, search engines; Ecommerce, Internet of Things, peer-to-peer, cloud; effects of usage on global bandwidth requirements.

LO2 Evaluate suitability of network protocols to meet application requirements, referencing appropriate standards

Network protocols:

TCP/IP and its relationship to the OSI model; Layer 2 protocols (e.g. Ethernet, spanning tree, MAC addressing, switch CAM tables); encapsulation used in cloud and software-defined networking (SDN) (e.g. VXLAN); virtual switches; Layer 3 routing, subnets, NAT, routing protocols (e.g. BGP, OSPF); client–server relationship to port numbers and understanding of session; DHCP; standards bodies (e.g. Internet Engineering Task Force (IETF)).

Application protocols:

Identify the main Internet services and their supporting protocols; web protocols (e.g. HTTP, SSH, FTP, DNS); services (e.g. web services, streaming, VOIP, real-time video, online gaming).

LO3 Produce network designs that conform to industry best practice to meet customer requirements

Key network components:

Switches, routers, firewalls, L3 switches, dense wavelength-division multiplexing (DWDM), load balancers, VPN; common servers (e.g. web, email, file, directory services); wireless infrastructure; cloud network components.

Network software and programming:

Client software, server software, client operating system, server operating system; network sockets, connection and connectionless approaches, socket states.

Network connectivity:

Wired (e.g. fibre optic, twisted pair, coaxial), wireless (e.g. 5G, satellite comms, WiFi); VPNs, secure connectivity; cloud connectivity; key networks (e.g. public switched telephone network (PSTN), 21st Century Network (21CN), Joint Academic Network (JANET), government networks such as Public Services Network (PSN)).

Design:

Use of design tools to create network diagrams, and white papers to identify manufacturer-suggested best practice; reinforce design decisions through experimentation; ensure provision of sufficient detail for designs to be implemented correctly.

LO4 Analyse the security threats faced by computer networks and communicate mitigation strategies.

Identification:

Designing networks to identify intrusions; continuous evaluation of active threats against current and future network designs; threat records (e.g. Common Vulnerabilities and Exposures (CVE)); real-time monitoring of systems; firewall monitoring; integration of Security Information and Event Management (SIEM) tools and Security Orchestration, Automation and Response (SOAR) tools.

Threats:

Identify the types of threats that are faced by computer networks: viruses, Trojans, advanced persistent threads, insider threats, malware, credentials, denial-of-service and state-sponsored threats; understanding the role of users as a threat.

Mitigation:

Methods used to mitigate or reduce the impact of a security incident: data protection; user behaviour; training; standards (e.g. Payment Card Industry Data Security Standard (PCI DSS), National Institute of Standards and Technology (NIST) 800); security testing, penetration testing and external auditing; endpoint protection (e.g. antivirus); identity and access management (IAM), multifactor authentication; reducing the attack surface; establishing teams and plans to respond to a security breach/threat.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss the evolution of the Internet, identifying major technological and usage transitions		**LO1 and LO2**
P1 Describe the main technological steps in the evolution of the Internet. **P2** Discuss how Internet use has changed with reference to more demanding latency and bandwidth requirements.	**M1** Analyse the latest and near-to-market methods of Internet connectivity.	**D1** Critically analyse the challenges and mitigations made when migrating to new protocols on the Internet.
LO2 Evaluate suitability of network protocols to meet application requirements, referencing appropriate standards		
P3 Identify the set of protocols that could be used to meet the requirements of an application. **P4** Evaluate standards documents to verify the operation of protocols.	**M2** Analyse the impact of cloud computing on protocol design.	
LO3 Produce network designs that conform to industry best practice to meet customer requirements		**LO3 and LO4**
P5 Produce a network for a given scenario to meet user requirements. **P6** Describe the operation of the main components used in computer networks.	**M3** Refine network designs through collaborative assessment.	**D2** Evaluate network designs against best practice provided by manufacturers and security bodies.
LO4 Analyse the security threats faced by computer networks and communicate mitigation strategies.		
P7 Analyse security threats faced by computer networks. **P8** Detail the design mitigations that should be included in defending a network against external and internal threats.	**M4** Research active threats and provide mitigation actions to given network designs.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Mishra, V.K. (2019) *Software Defined Networks*. Momentum Press.

Rohde, P.P. (2021) *The Quantum Internet: The Second Quantum Revolution*. Cambridge University Press.

Tanenbaum, A.S., Feamster, N. and Wetherall, D. (2021) *Computer Networks*. 6th Ed. Pearson.

Links

This unit links to the following related units:

Unit 5046 Analogue and Digital Communications

Unit 5049: Data Networks, Services and Security.

Unit 4066: Data and Information

Unit Code: K/650/2946

Level: 4

Credits: 15

Introduction

The proliferation of digital devices has led to the generation of huge amounts of information, which can give useful insights to individuals and organisations alike in building knowledge and making better-informed decisions. A good business rests on data analysis; therefore, the data industry continues to receive investments whereby information is absorbed, verbalised and illustrated in support of the strategic success of organisations. Likewise, data continues to be a priority for governments and the public because it is the fuel for security and the digital economy. However, processing data to produce information that is complete, useful and accurate depends on high-quality data. To be of value, the formats of qualitative and quantitative data must be fit for their intended uses in decision-making, planning and operations. This requires appropriate processes for the collection, storage and retrieval of data. In addition, to bring data to life it must be analysed with the correct toolkit to make it easier to understand; for example, to detect patterns and trends, and introduce meaning to what are otherwise just raw values.

This unit introduces students to the different types of data and the impact of data quality control on acquiring knowledge for decision-making and complex problem-solving in organisations. It explores industry software solutions available to collect, analyse and present data. Other topics include data quality assurance, data quality control, primary data collection methods (e.g. interviews, questionnaires and surveys), and data analysis techniques (e.g. data democratization, omitting useless data, building narrative, and data visualisation).

On successful completion of this unit, students will be able to explain the difference between data, information and knowledge, and examine the impact of data quality on producing information for decision-making within an organisational context. Furthermore, students will be able to demonstrate practical skills using methods for primary and secondary data collection. It will also allow students to show their ability to assess data analysis approaches and techniques. Hence, this unit helps students to develop industry-led skills, analysis and interpretation, which are crucial for developing the opportunity to progress to a range of roles within the data analytics sector; examples of such job titles being data specialists, data analysts and information analysts.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Investigate the difference between data and information for decision-making

LO2 Examine the impact of data quality on producing information for decision-making

LO3 Demonstrate methods for primary and secondary data collection

LO4 Assess data analysis methods and techniques to meet or exceed customer or organisational requirements and expectations.

Essential Content

LO1 **Investigate the difference between data and information for decision-making**

Data types:

Data types: nominal, ordinal, discrete and continuous

Data types in programming: string, character, integer, float and Boolean

Primary and secondary data

Qualitative and quantitative data

Internal and external data.

Data, information and knowledge:

Comparison based on description, format, representation, meaning, interrelation, features, interdependence, use cases for decision-making and research

Processing data within a business system to produce information and knowledge

Fundamentals of knowledge-based systems.

Decision-making:

Defining decision-making

Methodology to acquire knowledge for decision-making; for example, investigate, build constructive environment, generate alternatives, explore options, select best options, plan evaluation, make the decision

Decision tools (e.g. SWOT diagrams, decision-making diagram, decision matrix, strategy map).

LO2 **Examine the impact of data quality on producing information for decision-making**

Data quality:

Defining data quality

Expectations, specifications and requirements for data quality (e.g. comparability, uniqueness and correctness)

Optimum use of data quality (e.g. data quality in public health)

Open data quality.

Data quality assurance:

Data profiling to recover anomalies and inconsistencies in the dataset.

Data quality control:

Quality control process

Organisational procedures for accurately interpreting and implementing requirements, and recording information obtained from various stakeholders (e.g., manager, customer, technical specialist, end users); data quality management to meet or exceed stakeholder requirements and expectations

Decisions based on factors including the degrees of inconsistency, incompleteness, accuracy, precision, and missing/unknown data.

LO3 **Demonstrate methods for primary and secondary data collection**

Methods for primary and secondary data collection:

Primary data collection methods (e.g. interviews, questionnaires and surveys, observations, documents and records, focus groups and oral histories)

Secondary data collection based on reviews of public records, government publications, historical data, technical and trade documents, and so on.

Qualitative data collection methods:

Qualitative research methods (e.g. ethnographic, grounded theory and phenomenological).

Quantitative data collection methods:

Using data to determine values

Quantitative research approaches (e.g. descriptive, correlational, experimental and quasi-experimental).

LO4 **Assess data analysis methods and techniques to meet or exceed customer or organisational requirements and expectations.**

Analysis categories:

For example, descriptive analysis, exploratory analysis, diagnostic analysis, predictive analysis, prescriptive analysis

Big data analytics in engineering applications

Database-related analysis, data management and retrieval in databases, data warehousing for engineering systems.

Types of data analysis methods and techniques:

Data analysis methods (e.g. regression analysis, cluster analysis, cohort analysis, neural networks, factor analysis, data mining, text analysis)

Data analysis techniques (e.g. data democratization, omitting useless data, building narrative, data visualisation).

Software for data analysis:

Main options for such software, including SPSS, JASP, jamovi, GNU PSPP, RStudio, BlueSky Statistics, Rodeo (Python statistical analysis IDE), Juno IDE (Julia language IDE), business intelligence (BI) tools, statistical analysis, SQL consoles, and data visualisation

Business analytics tools (e.g. Board, Dundas BI, MicroStrategy, Sisense, Tableau big data analytics, Zoho Reports, and Jaspersoft BI tools).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the difference between data and information for decision-making		**LO1 and LO2**
P1 Explain the different types of data. **P2** Investigate how information enables decision-making.	**M1** Analyse the advantages and challenges of processing different data types to support decision-making in organisations.	**D1** Evaluate how processing and quality control of data and information affects how organisations solve complex problems.
LO2 Examine the impact of data quality on producing information for decision-making		
P3 Explain data quality and justify its importance for decision-making. **P4** Investigate the processes for data quality assurance and control.	**M2** Analyse the advantages and challenges of data quality assurance and control processes.	
LO3 Demonstrate methods for primary and secondary data collection		**LO3 and LO4**
P5 Describe different primary and secondary data collection methods. **P6** Compare qualitative and quantitative data collection methods.	**M3** Analyse how different data collection methods can be utilised for a given scenario.	**D2** Evaluate data collection and analysis methods to produce information within an organisational context to meet clients' requirements and expectations.
LO4 Assess data analysis methods and techniques to meet or exceed customer or organisational requirements and expectations.		
P7 Review different industry tools and software solutions available for analysing and visualising data. **P8** Suggest the use of industry software to manipulate data and prepare visual presentations for a given data set.	**M4** Prepare a visual presentation to summarise data for a given scenario.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Camões, J. (2016) *Data at Work: Best practices for creating effective charts and information graphics in Microsoft Excel*. New Riders.

Chambers, J.M. et al. (2018). *Graphical methods for data analysis*. Chapman and Hall/CRC.

Connolly, T. and Begg, C. (2015) *Database Systems: A Practical Approach to Design, Implementation, and Management*. 6th Ed. Pearson.

Lander, J.P. (2017) *R for Everyone: Advanced Analytics and Graphics*. 2nd Ed. Addison-Wesley.

Martinez, W.L., Martinez, A.R. and Solka, J.L. (2017). *Exploratory data analysis with MATLAB®*. Chapman and Hall/CRC.

Prabhakaran, S. (2016) *Introduction to R Programming*. Packt.

Washington, S. et al. (2020). *Statistical and econometric methods for transportation data analysis*. Chapman and Hall/CRC.

Zozus, M. (2017). *The data book: Collection and management of research data*. Chapman and Hall/CRC.

Websites

asq.org	American Society for Quality 'Data Collection & Analysis Tools' (Article)
http://www.analytixlabs.co.in	Analytixlabs 'What is the Difference Between Data and Information?' (Article)
http://www.jotform.com	Jotform 'Data Collection Methods' (Article)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Assarroudi, A. et al. (2018). Directed qualitative content analysis: The description and elaboration of its underpinning methods and data analysis process. *Journal of Research in Nursing*, 23(1), 42–55.

Choi, J.P., Jeon, D.S. and Kim, B.C. (2019). Privacy and personal data collection with information externalities. *Journal of Public Economics*, 173, 113–124.

Cooper, P. (2017). Data, information, knowledge and wisdom. *Anaesthesia & Intensive Care Medicine*, 18(1), 55–56.

Fiesler, C., Beard, N. and Keegan, B.C. (2020). No robots, spiders, or scrapers: Legal and ethical regulation of data collection methods in social media terms of service. In *Proceedings of the Fourteenth International AAAI Conference on Web and Social Media* (pp. 187-196).

Loomis, D.K. and Paterson, S. (2018). A comparison of data collection methods: Mail versus online surveys. *Journal of Leisure Research*, 49(2), 133–149.

Links

This unit links to the following related units:

Unit 4002: Engineering Maths

Unit 4003: Engineering Science

Unit 4061: Programming for Engineers

Unit 5049: Data Networks, Services and Security

Unit 5050: Machine Learning Systems and Programming.

Unit 4067: Digital Devices and Systems

Unit Code: L/650/2947

Level: 4

Credits: 15

Introduction

Most of the world is now dependent on infrastructure that uses digital technology. Digital electronics are used extensively in computing, data storage, communications, transport, navigation, financial systems, entertainment, and so on. It therefore follows that many industries, from gaming and complex graphics systems to Formula 1 racing, rely heavily on complex digital technology, usually in either hardware or software programmable form. As systems and infrastructure become more complex, it is vital that computer technicians and engineers have knowledge and skills in digital hardware as well as in software.

This unit introduces the fundamental principles of digital systems by way of simple functional building blocks using combinational and sequential logic. Using these blocks, it then looks at design techniques for building more complex functions. Most modern digital designs are now implemented with programmable technologies such as microcontrollers and/or programmable logic (e.g. field-programmable gate arrays (FPGAs), application-specific integrated circuits (ASICs), etc.) rather than using small-scale integrated circuits (SSIs) and medium-scale integrated circuits (MSIs). This unit focuses on the design of digital circuits in a hardware description language (HDL) environment, and physical implementation using a FPGA development board.

Prior to studying this unit, students are expected to have knowledge of the binary number system.

On successful completion of this unit, students will understand the concepts of digital systems and be able to identify the most common combinational and sequential digital building blocks. They will be able to use these blocks and traditional design techniques to build more complex digital functions. Students will be able to use an HDL and programmable logic to design and implement combinational and sequential circuits on a FPGA. This will provide students with the knowledge, understanding and skills to progress to further study in the use of this technology; to design and implement complex digital systems or to fulfil a technician role in industry.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Design combinational logic circuits for suitable applications

LO2 Design sequential logic circuits for suitable applications

LO3 Implement combinational and sequential logic circuits using a hardware description language (HDL) software package

LO4 Test combinational and sequential logic designs using a field-programmable gate array (FPGA) development board.

Essential Content

LO1 **Design combinational logic circuits for suitable applications**

Introduction to digital electronics:

Analogue (continuous) signals, digital representation, and the requirement for conversion between these forms; examples of analogue and digital data (e.g. temperature, digital music player, digital photography)

Need for processing, storing and communication of digital data (e.g. computers, mobile phones).

Combinational logic gates:

Symbols, truth tables, Boolean equations, and function of logic gates: AND, OR, NOT, XOR, NAND, and NOR

Application of relevant numerical skills (Binary, dotted decimal notation) required to meet the defined specifications.

Techniques used in combinational logic circuit design:

Boolean algebra, De Morgan's theorems, Karnaugh mapping

Combinational logic circuits involving up to 4 inputs and a maximum of 10 gates before minimisation

Optimisation of combinational logic circuits using the techniques listed above; circuits using basic logic gates to achieve more complex functions (e.g. adders, decoders, encoders, multiplexing and demultiplexing (MUX/DEMUX), parity checking, simple logic controls).

Introduction to digital technologies:

Use of complementary metal–oxide–semiconductor (CMOS) and transistor–transistor logic (TTL): speed, voltages, fan-out, power consumption, speed–power product, packing density

Recent silicon technologies

Concept of propagation delay and its implications; timing analysis of combinational circuits.

Simple testing methodologies:

Instrumentation (e.g. logic probe, oscilloscope, etc.)

Simulation software (e.g. NI Multisim).

LO2 **Design sequential logic circuits for suitable applications**

Sequential logic design:

Sequential building blocks: latches; D, T and JK flip-flops

Set-up and hold times – implication on maximum clock speed

Asynchronous and synchronous systems (e.g. compare synchronous and asynchronous counters)

Suitable sequential circuits built from D or JK flip-flops to include shift registers, synchronous counters, and sequence generators (up to and including 4 bits)

State diagrams to describe counters and sequence generators.

Testing sequential designs:

Use of oscilloscope (e.g. measuring clock frequency, propagation delays)

Use of simulator (e.g. NI Multisim).

LO3 **Implement combinational and sequential logic circuits for simple applications using a hardware description language (HDL) software package**

HDL:

Languages (VHDL and Verilog) – choose one to use

Structures: entity and architecture, and key words associated with the chosen language

Behavioural architecture.

Implementing combinational logic in HDL:

Entry of schematic and HDL (e.g. VHDL, Verilog) into HDL development software (e.g. Quartus (Intel), ISE Design Suite (Xilinx))

Compilation and debugging techniques

Suitable combinational logic circuits (e.g. adders, decoders, comparators, encoders, seven-segment display encoding, MUX/DEMUX, parity checking, simple logic controls).

Implementing sequential logic in HDL:

Suitable sequential logic circuits (e.g. shift registers, counters and sequence generators) written in HDL using dataflow and/or behavioural architecture.

LO4 **Test combinational and sequential logic designs using a field-programmable gate array (FPGA) development board.**

Field-programmable gate array (FPGA) technology:

Introduction to structure and complexity of current FPGA technology.

Simulation:

Use of HDL development tools to simulate combinational and sequential designs.

FPGA development boards:

Structure of a typical development board

Pin assignment, downloading, simulation, testing and verifying combinational and sequential designs

Ensure use of tools and techniques for secure operations and in testing network designs.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Design combinational logic circuits for suitable applications		
P1 Explain the different digital technologies used to implement digital circuits. **P2** Design suitable combinational logic circuits, making mostly accurate use of Boolean algebra and Karnaugh maps.	**M1** Analyse the different digital technologies used to implement digital circuits **M2** Design suitable combinational logic circuits, making accurate use of Boolean algebra, De Morgan's theorems and Karnaugh maps.	**D1** Evaluate the different digital technologies used to implement digital circuits. **D2** Evaluate the design of suitable combinational logic circuits, by accurately optimising them.
LO2 Design sequential logic circuits for suitable applications		
P3 Design suitable sequential logic circuits, using mostly accurate state diagrams.	**M3** Design suitable sequential logic circuits, using techniques accurately.	**D3** Design optimised suitable sequential logic circuits, using appropriate techniques accurately.

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Implement combinational and sequential logic circuits for simple applications using a hardware description language (HDL) software package</td><td rowspan="4">LO3 and LO4

D4 Evaluate the correct operation and improved performance of at least two suitable combinational and two sequential logic circuits, comparing the results from accurate HDL simulations and FPGA hardware functional tests.</td></tr>
<tr><td>P4 Implement, using schematic entry, two suitable combinational and two suitable sequential logic circuits.</td><td>M4 Implement, using both schematic entry and HDL, two suitable combinational and two suitable sequential logic circuits.</td></tr>
<tr><td colspan="2">LO4 Test combinational and sequential logic designs using a field-programmable gate array (FPGA) development board.</td></tr>
<tr><td>P5 Verify the correct operation of two suitable combinational and two suitable sequential logic circuits using simulation and safe functional tests on FPGA hardware.

P6 Explain, using the HDL simulation and FPGA hardware test results, the correct operation of at least three logic circuits, combinational and sequential.</td><td>M5 Verify the correct operation and improved performance of two suitable combinational and two suitable sequential logic circuits using simulation and safe functional tests on FPGA hardware.

M6 Analyse, using the HDL simulation and FPGA hardware test results, the correct operation and improved performance of at least three logic circuits, combinational and sequential.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Floyd, T.L. (2015) *Digital Fundamentals*. 11th Ed. Pearson.

Kleitz, W. (2014) *Digital Electronics: A Practical Approach with VHDL*. 9th Ed. Pearson New International Edition. Pearson Education.

Mano, M.M. and Ciletti, M.D. (2022) *Digital Design: With an Introduction to the Verilog HDL, VHDL and SystemVerilog*. 6th Ed. Pearson.

Short, K. (2014) *VHDL for Engineers*. Pearson New International Edition. Pearson Education.

Websites

http://www.intel.com	Intel 'Intel® FPGA Academic Program' (General reference)
http://www.xilinx.com	Xilinx 'Xilinx University Program' (General reference)

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 4064: Analogue and Digital Electronics

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit 5043: Digital System Design.

Unit 4068: Industrial Robots

Unit code	**L/617/3940**
Unit level	**4**
Credit	**15**

Introduction

Industrial robotics is the present and future of automated manufacturing and is an unstoppable reality. With the emergence of lighter, smarter and safer industrial robot models that are increasingly easy to interface, the demand has never been so high and is expected to grow year on year. Popular applications for industrial robots include welding, painting, assembly and materials handling. Modern industrial robots are now an integral part of cyber-physical mechatronic systems contributing to Industry 4.0 manufacturing.

The aim of this unit is for students to investigate the range, operation and benefits of industrial robots within manufacturing applications. Among the topics included are industrial robot selection, and programming and safety protocols that anticipate future developments in industrial robot technology.

On successful completion of this unit students will have an understanding of the electrical, mechanical, hydraulic and pneumatic operation of common industrial robots, how to select and program an industrial robot for a given requirement, taking account of safety considerations, and how to assess the economic future of robot technologies in manufacturing.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries

LO2 Explain the safety standards associated with industrial robots

LO3 Program an industrial robot for automated process application

LO4 Investigate the global economic scope of industrial robots and integration into smart factories.

Essential Content

LO1 **Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries**

Types and selection:

Operational characteristics: Cartesian, cylindrical, spherical, toroidal, SCARA

Selection: number of axes; load, orientation, speed, travel, precision, environment and duty cycle parameters (LOSTPED); anthropomorphic robots

Common Brands: e.g. Fanuc, Yaskawa and ABB.

Applications:

Welding, painting, material handling, packaging, assembly, inspection, dangerous and robust working environments, repetitive tasks.

Operation and characteristics of 6-axis industrial robots:

Controller: motion controller, motor drives, power supplies, human−machine interface (HMI)

Manipulator: sensing, brakes, axis motor, effector motor, environment sensing

Tooling: grippers, types, interfaces

Axis operation: purpose of each axis, work area, reach, wrist roll, pitch and yaw motion, rotation, home position and calibration

End effectors: types of gripper tools and hands, two-jaw, vacuum and magnetic.

LO2 **Explain the safety standards associated with industrial robots**

Safety standards:

Functional Safety: IEC61508, Hazard and Risk Assessment

Robot and robot system safety: ANSI/RIA R15.06-2012, BS EN ISO 10218:2011

Cell safety features: operating envelope, space restrictions; operating safeguards, emergency stops, guarding, barriers, interlocks, light curtains, laser, two-hand controls, scanners, floor mats; barrier sizing – around, under, through, over (AUTO)

Operational modes, user interfaces

Safety first culture within the context: health and safety policies, procedures and regulations, compliance, risk management and mitigation.

LO3 **Program an industrial robot for automated process application**

Software:

Latest tools and technologies to aid programming of industrial robots.
For example: data objects, instruction lists, BASIC, MATALB, Python, Yaskawa, MotoSim Enhanced Graphic Virtual Robot Control, ABB, RobotStudio, Fanuc Roboguide, Denso Wincaps III.

Robot application programming:

Types: joint-level, robot-level and high-level programming

Command and control: graphical user interfaces, point-n-click, scheduling software

Tasking software: drag-n-drop, specific application deployment, scripted language, lead by the nose

Online: joysticks, pendants, jogging, modifying existing positions

Computer simulation offline programming

Controlling robots with programmable logic controllers (PLCs; see *Unit 18*)

Robot commands: motion, interlock and sensor

Manufacturers' languages: ABB Rapid, Kuka KRL, Yaskawa Inform

Case studies: Team programming projects, peer evaluations and professional discussions.

LO4 **Investigate the global economic scope of industrial robots and integration into smart factories.**

Economic scope:

Major markets: Japan, USA, China, South Korea, Germany

Application demand: automotive, electrical and electronics, metal

Robot density; impact on workforce; training of workforce.

Advances in robot technology:

Machine vision, artificial intelligence (AI), collaborative robots (cobots), Internet of Things (IoT), edge computing, simplified integration, networked robots, cloud robotics, virtual reality robots; training of robots; role of robotics in Industry 4.0.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries		**LO1 and LO2**
P1 Review the types of industrial robots and their applications within manufacturing industries. **P2** Describe selection criteria for industrial robot applications.	**M1** Analyse the features and operation of six axis robots within manufacturing applications.	**D1** Evaluate the selection of a safety-compliant industrial robot system for a given manufacturing application.
LO2 Explain the safety standards associated with industrial robots		
P3 Outline the principles and methods of functional safety analysis within automated manufacturing. **P4** Explain the safety criteria for robot cells within manufacturing applications.	**M2** Develop hazard and risk assessment for an industrial robot manufacturing system.	
LO3 Program an industrial robot for automated process application		
P5 Investigate the range of programming languages and methods available for industrial robots. **P6** Program an industrial robot to perform a simple task.	**M3** Analyse offline and online programming methods for industrial robots.	**D2** Design, develop and test a robot program for a series of automated industrial tasks.
LO4 Investigate the global economic scope of industrial robots and integration into smart factories.		
P7 Assess the advantages and scope of collaborative robots over traditional methods. **P8** Investigate advances in industrial robot technology.	**M4** Analyse the benefits of artificial intelligence within industrial robotics and contribution to Industry 4.0.	**D3** Evaluate the global economics of increased robot density in smart factories and the impact on the human workforce.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Blume C., K. Selke and Jakob W. (2011) *Programming Languages for Industrial Robots − Artificial Intelligence (Paperback).* Springer-Verlag Berlin and Heidelberg GmbH & Co. KG.

Calinon S. (2021) *Robot Programming by Demonstration (Hardback).* Taylor & Francis Inc.

Doulgeri Z. and Dimeas F. (Editors) (2023) *Human-Robot Collaboration: Unlocking the potential for industrial applications − Control, Robotics and Sensors (Hardback).* Institution of Engineering and Technology.

Dum B. (2021) *The Complete Guide to Programming a Robotics for Dummies: Build, Analysis, Control, Applications, Autonomous, Defending Human Expertise, Machine Learning, And Virtual (Paperback).*

Eteokleous N. and Nisiforou E. (Editors) (2021) *Designing, Constructing, and Programming Robots for Learning (Hardback).* IGI Global.

Engelberger J.F. (2012) *Robotics in Practice: Management and Applications of Industrial Robots*. Berlin: Springer.

Grau A. and Wang Z. (Editor) (2020) *Industrial Robotics: New Paradigms (Hardback).* IntechOpen.

Lazarescu M., Biradar R.C., Geetha D., Tabassum N. and Hegde N. (Editors) (2023) *AI and Blockchain Applications in Industrial Robotics (Hardback).* IGI Global.

Nagat F. and Watanabe, K. (2013) *Controller Design for Industrial Robots and Machine Tools: Applications to Manufacturing Processes*. Cambridge: Woodhead Publishing in Mechanical Engineering.

perlberg J. (2016) *Industrial Robotics*. Boston: Cengage Learning.

Petrič T., Ude A. and Leon Žlajpah L. (Editors) (2023) *Advances in Service and Industrial Robotics: RAAD 2023 − Mechanisms and Machine Science 135 (Hardback).* Springer.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Automation and Remote Control

Automation

IFAC Journal of Systems and Control

IEEE Journal on Robotics and Automation

International Journal of Automation and Control (IJAAC)

Journal of AI, Robotics and Workplace Automation

Journal of Automation and Intelligence

Programmable Logic Controllers (Special issue)

Robotics

Links

This unit links to the following related units:

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 4016: Instrumentation and Control Systems

Unit 4030: Industry 4.0

Unit 4033: Programmable Logic Controllers (PLCs)

Unit 5009: Further Programmable Logic Controllers (PLCs)

Unit 5021: Further Control Systems Engineering.

Unit 4069: Properties and Applications of Materials and Emerging Materials Pre-Production

Unit code	**T/617/3947**
Unit level	**4**
Credit value	**15**

Introduction

Manufacturing industries are dependent upon materials, and those working within this sector need an awareness of the materials available to them. The range is great and varied, and continually increasing as new and emerging technologies demand ever more sophisticated materials. Indeed to retain a competitive edge, the constant development of materials and their potential to be adapted, is key. So for a range of sectors, including the automotive industry, textiles, consumer goods and many other types of manufacturing, materials play a fundamental role.

For a given product to achieve its desired potential and to work effectively, it is important to select an appropriate material for its manufacture. In order to ascertain the most appropriate material, it is first necessary to understand the requirements of the product and the conditions under which it will operate. By acknowledging these desired properties, it is then possible to select the material best suited for the product.

Increasingly it is common to find that an array of several material types is necessary for even the simplest application or product. A good knowledge of how these materials behave, both independently and in conjunction with each other, and an awareness of how proprieties can be altered by treatments, processing or additives, is of prime importance to ensure the product is fit for purpose.

This unit will provide students with the necessary background knowledge to identify material types and develop an awareness of the range and potential capabilities of materials at their disposal. Students will be introduced to the structure of differing material groups and how this affects the properties, physical nature and performance characteristics of common manufacturing materials. How properties can be modified will also be addressed, as will the advances in material technology which brings new capabilities to industry.

Note regarding delivery of this unit: This unit has been designed to consider the use of materials across a range of manufacturing sectors, including, but not limited to, the automotive, food and drink, and textile manufacturing industries. The *Essential Content* section has been designed to be intentionally broad; however it is for individual Centres to focus on the relevant material types for a particular manufacturing sector. The use of e.g. within the *Essential Content* allows for Centres to select and focus on particular areas of delivery.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Define the properties necessary for a given product to function as required under its intended service conditions

LO2 Review the properties of a material and show how these are affected by its structure

LO3 Determine the material most suited for a given application

LO4 Explain the methods by which a material can be modified to enhance its use for a particular application.

Essential Content

LO1 **Define the properties necessary for a given product to function as required under its intended service conditions**

Define the needs of the product in terms of properties:

Mechanical

Chemical

Electrical

Thermal

Magnetic

Optical and aesthetic properties

Colourfastness

Dye acceptance

Comfort

Value for money

Recyclability.

Define the properties in terms of their characteristics:

Hardness

Toughness

Ductility

Conductivity

Durability

Resistance to stains

Resistance to environmental factors

Insulating capability

Flammability

Resistance to fatigue or corrosion.

LO2 Review the properties of a material and show how these are affected by its structure

Material categories, e.g.:

Polymers: commodity plastics, engineering plastics, elastomers, bioplastics

Metals: ferrous, non-ferrous, alloys

Ceramics: glass, traditional, advanced

Composites: long and short glass-reinforced polymers, carbon-reinforced polymers, reinforced ceramics, nano-reinforcement

Natural materials: wool, cotton, hemp, coir, silk

Emerging specialist materials: aerogels, shape-memory alloys, super-hydrophilic materials, self-healing materials, multi-functional materials, biomaterials.

Material structure:

Polymers: thermoplastic, thermoset, amorphous, crystalline

Metals: crystalline structures – body-centred and face-centred cubic lattice and hexagonal close-packed structures; characteristics and function of ferrous metals; non-ferrous phase diagrams

Ceramics: molecular structure – electrostatic covalent and ionic bonding

Composites: matrix and reinforcement forms

Textiles: yarn structure – distribution of fibres within the yarn, quantity of fibres within the cross section, orientation and position of fibres, fibre length, degree of twist.

LO3 Determine the material most suited for a given application

General factors to be considered:

Functional demands of product design

Compatibility of multiple material components in a given application, under a range of expected conditions

Recyclability of the product, particularly where multiple component parts are required.

Categorisation of materials by their properties:

Physical, e.g.: thermal, optical, magnetic, electrical, handling

Mechanical and surface/environmental, e.g.: resistance to oxidation and/or corrosion, durability, resistance to damage, resistance to stains, resistance to shrinkage

Aesthetic and sensory, e.g.: colour, comfort, feel, ease of handling, fragility.

The effect of secondary processes or treatments on material properties, e.g.:

Heat treatment and mechanical processes

Surface modifications, such as painting and electroplating.

Service life of the product and the conditions under which it will operate, e.g.:

Durability of materials; resilience to change of temperature, moisture etc.

Repairability versus obsolescence; possibility of replacing parts.

Economic factors in selection, e.g.:

Forms of supply

Cost and availability

Viability of producing the quantities required.

Impact of environmental concerns, public perception and government policy/legislation on material selection, e.g.:

Procurement from sustainable sources, e.g. rainforest-friendly, fair trade; best practice in mining and raw material manufacture; carbon footprint of raw material manufacture; proposed legislation on ecocide

Packaging and whether biodegradable, recyclable or reusable

Relevant regulations on safety of products.

LO4 **Explain the methods by which a material can be modified to enhance its use for a particular application.**

Options available to enhance specific properties, e.g.:

Mechanical manipulation, processing adaptations, heat treatments, weaving techniques.

Additive inclusion, e.g.:

Particulate fillers, reinforcements (nano-particles to long fibres), antioxidants, antiozonates.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Define the properties necessary for a given product to function as required under its intended service conditions		
P1 Select a relevant product; describe its features in terms of its function and/or service requirements.	**M1** Analyse the functions, defined in engineering terms, required for a given product when in service.	**D1** Evaluate any potential limitations binding this product in terms of e.g. quantities required and environmental considerations.
LO2 Review the properties of a material and show how these are affected by its structure		
P2 Explain the properties of a given material set and show how structure influences these properties.	**M2** Investigate emerging materials and suggest ways these may enhance the range of materials on offer.	**D2** Evaluate why the behaviour of a material is considered such an important factor when selecting a material for a given product or application.
LO3 Determine the material most suited for a given application		
P3 Explain the properties that make a material suitable for a given product. **P4** Explore how the material(s) of choice would be expected to behave in service.	**M3** Analyse the considerations required when selecting a material for a given application, particularly in terms of compatibility with e.g. adjoining materials, the user, secondary treatments or processes.	**D3** Evaluate how government policy/legislation, public opinion and environmental factors influence the selection of a material for an application.
LO4 Explain the methods by which a material can be modified to enhance its use for a particular application.		
P5 Define how a particular materials can be modified to enhance its behaviour to achieve a specified change in the performance of that material.	**M4** Investigate the advantages of modifying a material over simply selecting another material.	**D4** Evaluate material modification through the incorporation of secondary phases or using other manufacturing manipulations.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby, M. (2016) *Materials Selection in Mechanical Design*. 5th ed. Amsterdam: Elsevier.

BLACK, J.T. and Kohsher, R.A. (2017) *Degarmo's Materials and Processes in Manufacturing.* 12th ed. Oxford: John Wiley and Sons.

Callister, W. and Rethwisch, D. (2016) *Fundamentals of Materials Science and Engineering: An Integrated Approach*. 5th ed. Oxford: John Wiley and Sons.

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http://www.textilemates.com	Textile Mates Yarn Structure Properties (General reference)
http://www.americanchemistry.com	American Chemistry Council The Basics: Polymer Definition and Properties (General reference)
http://www.substech.com	Substances and Technologies (General references)

Links

This unit links to the following related units:

Unit 4009: Materials, Properties and Testing

Unit 4028: Materials Engineering with Polymers

Unit 4073: Sustainability and the Environment in the Manufacturing Industry.

Unit 4070: Command and Control Systems

Unit code	**R/617/3664**
Unit level	**4**
Credit value	**15**

Introduction

The systems that enable a railway to function in an optimum way fall under the area of Command, Control and Communication (CCC). Such railways operate in a safe and timely fashion, and without any delays or cancellations. CCC specialists operate and maintain these systems to ensure the trains operate as planned thus ensuring the passengers enjoy a great service.

This unit focuses on the various systems and subsystems that make up the CCC. Initially, it establishes what CCC is, its purpose and principle of operation. It then goes on to discuss design considerations, such as how health and safety may be embedded into the system, aspects of protection, considers risk and failure modes as well as ergonomic and human factors, IT systems, telecommunications, cybersecurity, and operational and maintenance aspects for the CCC system. The unit then focuses on the Common Safety Method for Risk Evaluation and Assessment (CSM RA), and the European Rail Traffic Management System (ERTMS) and its subsystems: Global System for Mobile Communications – Railway (GSM-R), European Train Control System (ETCS) and European Train Management Layer (ETML).

Students who have completed this unit as part of their HNC studies will be very well placed to apply for employment as Command, Control and Communications (CCC) Advanced Technicians or other similar roles within the railway industry.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the function of the Control, Command and Communication (CCC) system and the role it plays in the operation of a railway

LO2 Explore CCC design factors and operational considerations

LO3 Explain the Common Safety Method (CSM)

LO4 Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).

Essential Content

LO1 Explain the function of the Control, Command and Communication (CCC) system and the role it plays in the operation of a railway

The Control, Command and Communication (CCC) system:

Determining what the CCC system is

The CCC system function and principle of operation

The function and principle of operation of each CCC subsystem.

Legacy, modern and future rail signalling and train control systems:

Similarities and differences between the various systems.

LO2 Explore CCC design factors and operational considerations

Design factors:

Embedding health and safety into the CCC system

Building protection into the design

Risk and failure modes

Ergonomic and human factors

IT systems − architecture, hardware and software

Security technology − cybersecurity considerations, precautions and levels of access

Telecommunications systems.

Operational considerations:

Operational and maintenance requirements

Demonstrating that operational and maintenance requirements are successfully met.

The commissioning certification process:

Designing, implementing and operating a CCC system.

Purpose and processes management:

For data, configuration and change.

LO3 **Explain the Common Safety Method (CSM)**

The need for CSM:

Safety requirements in a competitive environment

Risk evaluation and assessment

Processes harmonisation for risk evaluation and assessment.

Risk management process of CSM RA:

The framework of the risk management process

Analysis and evaluation of hazards

Producing suitable and sufficient risk assessment for a change

Proposing a technical, operational or organisational change.

LO4 **Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).**

The European Rail Traffic Management System (ERTMS):

The ERTMS system of standards

Purpose, targets and developments

ERTMS function and operation

Implementation and deployment strategies.

The Global System for Mobile Communications – Railway (GSM-R):

Communicating between train and trackside

The GSM-R principle of operation

GSM-R capabilities and limitations

Subsequent communication evolutions.

The European Train Control System (ETCS):

The need for ETCS and its importance to safety

ETCS principle of operation

ETCS numbering levels

Implementation and deployment.

The European Train Management Layer (ETML):

Intelligently optimising train movements

ETML principle of operation and functional structure.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the function of the Control, Command and Communication (CCC) System and the role it plays in the operation of a railway		
P1 Describe the function of the CCC system as used in the railway. **P2** Explain the principle of operation of the CCC system.	**M1** Explore the principle of operation of the various CCC subsystems.	**D1** Explain how rail signalling and train control systems evolved.
LO2 Explore CCC design factors and operational considerations		
P3 Explain the need to embed health and safety aspects in a CCC system during the design phase. **P4** Explain why protection must be built in a CCC system during the design phase.	**M2** Discuss operational and maintenance requirements in railway CCC systems and explain how they can be successfully met.	**D2** Justify the importance of incorporating cybersecurity in a CCC system and highlight how the system could be compromised if it gets cyberattacked.
LO3 Explain the Common Safety Method (CSM)		
P5 Explain why safety requirements were considered a barrier to open competition across EU railways. **P6** Explain how CSM RA enables processes harmonisation for risk evaluation and assessment.	**M3** Analyse the framework of the CSM RA risk management process explaining three risk acceptance principles.	**D3** Investigate, with the use of examples, how the CSM RA could be put to use when a technical, operational or organisational change is proposed.
LO4 Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).		
P7 Describe the problem that the ERTMS was developed to solve. **P8** Explain the technical targets of ERTMS.	**M4** Evaluate each ETCS and interpret its various numbering levels using a comparative table.	**D4** Evaluate ERTMS implementation strategies focusing on the main factors that compromised deployment efforts.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Hall, C. (2016) *Modern Signalling Handbook*. 5th ed. Shepperton: Ian Allan Publishing.

Yu, F.R. (2018) *Advances in Communications-Based Train Control Systems*. London: CRC Press.

Websites

orr.gov.uk	Office of Rail Regulation Common Safety Method for Risk Evaluation and Assessment (Guidance)
uic.org	Worldwide Railway Organisation ERTMS (Article)
irse.org	Institute of Railway Signal Engineers Technology Updates (General reference)
ertms.net	ERTMS ERTMS Updates (General reference)

Links

This unit links to the following related units:

Unit 4016: Instrumentation and Control Systems

Unit 4047: Railway Operations

Unit 4052: Railway Telecommunications

Unit 4055: Management and Operations

Unit 4057: Networking

Unit 4059: Computer Systems Architecture

Unit 4071: Introduction to Signalling Systems.

Unit 4071: Introduction to Signalling Systems

Unit code T/651/0805

Unit level 4

Credit value 15

Introduction

This unit aims to provide students with an underpinning knowledge of signalling, why signalling is provided, and also how it interfaces with other railway engineering disciplines and railway operations.

Students will consider different types of interlocking systems and which train detection systems are used in each type. An appreciation of railway operation will be given when discussing block systems as well as exploring the purpose of signalling from first principles, while considering the necessity for signals and their relationship within the modern railway.

The knowledge and understanding gained in this unit will enable students to make an informed choice should they choose to specialise in signal engineering or, alternatively, a thorough appreciation of the subject should they prefer to pursue other disciplines.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate the meaning of signals and indicators provided on UK railways

LO2 Discuss the merits of various interlocking systems

LO3 Explore the necessity for train detection systems and how they are applied within the signalling system

LO4 Identify different types of block systems for single and double line railways.

Essential Content

LO1 **Evaluate the meaning of signals and indicators provided on UK railways**

The development of signals

Historical background from hand signalling by 'policemen' to semaphore signals.

Further development with the greater use of electricity

First with power operation, then development of colour light signals in conjunction with more complex interlocking systems.

Signals in the cab

The migration to cab signalling and indicators

The case for removing wayside signals altogether.

LO2 **Discuss the relative merits of various interlocking systems**

The purpose of interlocking

Historical overview, why it is necessary, what it achieves.

Mechanical interlocking

Principles, use in conjunction with block systems.

Electro-mechanical interlocking

Development from mechanical systems, greater use of electricity within interlocking and wayside signalling.

Electrical interlocking

Types of relay interlockings, comparison with merits of earlier/later interlocking technology, ease of design, installation, test and subsequent modification.

Electronic interlocking

Development of electronic interlockings, principles, management of data, interfacing with other systems, e.g. European Train Control System.

LO3 **Explore the necessity for train detection systems and how they are applied within the signalling system**

The origin of train detection

Historical overview with early applications

The difference between contacting and non-contacting systems, why it is necessary and what it achieves.

Application of track circuits

Use in conjunction with the absolute block system and subsequent development of the track circuit block system with greater use of centralised control.

Communications Based Train Control (CBTC)

Train detection using radio position reports sent from the train to the wayside equipment as used in moving block systems.

LO4 **Identify different types of block systems for single and double line railways.**

Block systems

The difference between block systems required for train separation on single line railways and double line railways.

Single line railways

Development from one train working through various systems (staff and token working to acceptance levers) to track circuit block.

Double line railways

Development from time interval working through various systems (absolute block, track circuit block) to moving block systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the meaning of signals and indicators provided on UK railways		
P1 Review the evolution of signaling technology from hand signalling through to cab signalling. **P2** Assess the implications of cab signaling and indicators on wayside signalling.	**M1** Compare and contrast the difference between junction signalling using semaphore signals and colour light signals.	**D1** Critically evaluate the reasons for providing different controls for junction signals, considering the advantages and disadvantages of each.
LO2 Discuss the merits of various interlocking systems		
P3 Explore the development of the interlocking systems and the link between points and signals. **P4** Determine the advantages and disadvantages between mechanical, electro-mechanical, electrical and electronic interlocking systems.	**M2** Assess the use of mechanical signalling in conjunction with block systems.	**D2** Compare the merits of relay interlocking with earlier/later interlocking technology, considering design, installation, test and subsequent modification.

Pass	Merit	Distinction
LO3 Explore the necessity for train detection systems and how they are applied within the signalling system		
P5 Explore the development of train detection systems and the application of track circuits. **P6** Discuss the CBTC system and its importance in communicating the position of the train to the block system wayside equipment.	**M3** Assess the uses of train detection with respect to the interlocking and block systems.	**D3** Investigate the differences between track circuits, train detection and CBTC detection, considering the benefits of each.
LO4 Identify different types of block systems for single and double line railways.		
P7 Differentiate between the principles of the absolute block system and the track circuit block system. **P8** Identify the main characteristics of electric token working for single line railways.	**M4** Produce control tables for aspect controls of a junction signal using the track circuit block system.	**D4** Critically evaluate the differences between track circuit block and moving block systems, in particular where application of one of these would have advantages over the other.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ellis, I. (2015) *Ellis' British Railway Engineering Encyclopedia.* 3rd ed. North Carolina: Lulu Press, Inc.

Hall, C. (2019) *abc Modern Signalling Handbook.* 5th ed. Shepperton: Ian Allan Publishing.

Woodbridge, P.J. (2018) *A Chronology of UK Railway Signalling 1825 – 2018.* London: Independent Publishing Network.

Websites

rssb.co.uk	Rail Safety and Standards Board Standards catalogue (General reference)
irse.org	Institution of Railway Signal Engineers Knowledge (General reference)
signalling-and-telecommunications.uk	Signal & Telecommunications UK Trainee revision questions Training
signalbox.org	Railway signalling Signals (General reference)

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4047: Railway Operations

Unit 4052: Railway Telecommunications

Unit 4053: Traction and Rolling Stock Systems

Unit 4057: Networking

Unit 4058: Strategic Information Systems

Unit 4070: Command and Control Systems.

Unit 4072: Construction Technology

Unit code	**Y/615/1388**
Unit level	**4**
Credit value	**15**

Introduction

The basic principles of construction technology have not changed for hundreds of years. However, the materials and techniques used to achieve these basic principles are constantly evolving; to enable the construction industry to deliver better quality buildings. Scarcity of resources and the continuing demand of more sophisticated clients, end users and other stakeholder interests, are driving the construction industry to provide buildings which facilitate enhanced environmental and energy performance, and greater flexibility, in response to ever increasing financial, environmental, legal and economic constraints.

This unit will introduce the different technological concepts used to enable the construction of building elements; from substructure to completion, by understanding the different functional characteristics and design considerations to be borne in mind when selecting the most suitable technological solution.

Topics included in this unit are: substructure, superstructure, finishes, building services and infrastructure components. On successful completion of this unit a student will be able to analyse scenarios and select the most appropriate construction technology solution.

*This unit is the same unit as *Unit 2: Construction Technology* in the *Pearson BTEC Higher Nationals in Construction*

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the terminology used in construction technology

LO2 Describe the different techniques used to construct a range of substructures and superstructures, including their function and design selection criteria

LO3 Identify the different types of civil engineering/infrastructure technology used in support of buildings

LO4 Illustrate the supply and distribution of a range of building services and how they are accommodated within the building.

Essential Content

LO1 **Explain the terminology used in construction technology**

Types of construction activity:

Low, medium and high-rise buildings, domestic buildings, for example house, flats and other multi-occupancy buildings, commercial buildings, for example offices and shops, industrial buildings, for example, light industrial and warehouses.

Construction technology terminology:

Loadbearing and non-loadbearing, structural stability, movement and thermal expansion, durability, weather and moisture resistance, aesthetics, fire resistance, sound insulation, resistance to heat loss and thermal transmission, dimensional co-ordination and standardisation, sustainability and scarcity of availability, on-site and off-site construction, legal requirements, buildability, health and safety.

Construction information:

Drawings, specification, schedules, CAD, Building Information Modelling (BIM).

Sustainability:

Supply chain

Lifecycle

'Cradle-to-grave'

'Cradle-to-cradle'

Circular economies.

LO2 **Describe the different techniques used to construct a range of substructures and superstructures, including their function and design selection criteria**

Pre-design studies:

Desk-top, Site Reconnaissance, Direct Soil Investigation techniques.

Substructure functions and design considerations:

Different methods for gathering disturbed and undisturbed samples, influence of soil type on foundation design, including water and chemical content, potential loads, position of trees and the impact on foundations, economic considerations, legal considerations (health and safety work in excavations), building regulations, plant requirements.

Types of foundations:

Shallow and deep foundations, strip and deep strip foundations, pad foundations, raft foundations, piled foundations (replacement and displacement piles).

Types of superstructure:

Traditional construction, framed construction: steel, composite concrete and steel, timber

Walls; roofs; structural frames; claddings; finishes; services.

Walls:

External walls: traditional cavity, timber frame, lightweight steel

Cladding: panel systems, infill systems, composite panel systems, internal partition walls.

Roofs:

Pitched and flat roof systems, roof coverings.

Floors:

Ground floors, intermediate floors, floor finishes.

Staircases:

Timber, concrete, metal staircases, means of escape.

Finishes:

Ceiling, wall and floor finishes.

LO3 **Identify the different types of civil engineering/infrastructure technology used in support of buildings**

Site remediation and de-watering:

Contamination management: cut-off techniques, encapsulation

Soil remediation: stone piling, vibro-compaction

De-watering: permanent sheet piling, secant piling, grout injection freezing, temporary techniques, such as pumping, wells, electro-osmosis.

Substructure works:

Basement construction: steel sheet piling, concrete diaphragm walls, coffer dams, caissons, culverts.

Superstructure works:

Reinforced concrete work: formwork, reinforcement, fabrication, concrete, steel.

LO4 **Illustrate the supply and distribution of a range of building services and how they are accommodated within the building.**

Primary service supply:

Cold water

Gas

Electricity.

Services distribution:

Hot and cold water

Single phase and 3-phase electricity

Air conditioning ductwork.

Services accommodation:

Raised access flooring

Suspended ceilings

Partitioning

Rising ducts.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the terminology used in construction technology		
P1 Describe the differences between residential, commercial and industrial buildings. **P2** Explain how the functional characteristics and design selection criteria are informed by proposed building use. **P3** Discuss the ways in which sustainability can be promoted in building projects.	**M1** Apply the terminology used in construction technology to a given building construction project.	**D1** Evaluate how the functional characteristics and design selection criteria impact on the eventual design solution.
LO2 Describe the different techniques used to construct a range of substructures and superstructures, including their function and design selection criteria		**LO2 and LO3**
P4 Describe the pre-design studies carried out and types of information collected for a given construction site. **P5** Explain the functional characteristics and design criteria for primary and secondary elements of a building substructure and superstructure.	**M2** Analyse how site conditions impact on the design of foundations. **M3** Illustrate how the component parts of an element allow it to fulfil its function.	**D2** Prepare a design report identifying superstructure, substructure and civil engineering structures necessary for a given building construction project.
LO3 Identify the different types of civil engineering/infrastructure technology used in support of buildings		
P6 Describe techniques used for remediating the site prior to construction commencing. **P7** Describe the types of substructure works carried out by civil engineers.	**M4** Compare different types of structural frame used to carry the primary and secondary elements of the superstructure.	

Pass	Merit	Distinction
LO4 Illustrate the supply and distribution of a range of building services and how they are accommodated within the building.		
P8 Describe the supply arrangements for primary services. **P9** Explain the distribution arrangements for primary services.	**M5** Demonstrate the elements of the superstructure used to facilitate the primary services.	**D3** Appraise how the distribution of the primary services impact on the overall design of the building.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bryan, T. (2010) *Construction Technology: Analysis and Choice*, Oxford: Blackwell.

Chartlett, A. and Maybery-Thomas, C. (2013) *Fundamental Building Technology.* 3rd Ed. Abingdon: Routledge.

Chudley, R. et al. (2012) *Advanced Construction Technology*. 5th Ed. Harlow: Pearson Education Limited.

Chudley, R. and GRENNO, R. (2016) *Building Construction Handbook*. Abingdon: Routledge.

Fleming, E. (2005) *Construction Technology: An Illustrated Introduction*. Oxford: Blackwell.

Links

This unit links to the following related units:

Unit 4048: Track Design

Unit 4060: Surveying, Measuring & Setting Out.

Unit 4073: Sustainability and the Environment in the Manufacturing Industry

Unit code	**A/617/3934**
Unit level	**4**
Credit value	**15**

Introduction

The challenges arising from a desire to live and work in a sustainable environment are confronting us now as never before. This is being felt across all industries and aspects of life with resources such as food, water, energy and even source materials becoming ever more precious.

Climate change is a scientifically attested phenomenon, with many international government agencies acting to reverse its impact. Furthermore, there is now an increased awareness, and indeed urgency, being felt on a communal level regarding our treatment of the planet. This has clear implications for the way we use our natural resources and how we manage the life cycles of our manufactured products. For instance a common theme, increasingly vocalised, relates to ocean health, as heightened awareness of the damage caused by our discarded waste becomes evident. An awareness of these issues, particularly in relation to resources, energy consumption, reuse, life cycle analysis and post-life management, is key. A deeper understanding of the issues at play is also necessary, as is the need to avoid vilifying certain materials without a fuller analysis of the potential role they can play in supporting sustainability.

The aim of this unit is to equip the student with a wide range of knowledge and understanding of the issues and topics associated with sustainability, particularly in terms of materials, energy, consumerism and manufacture/design. The students will be introduced to lean practice, relevant legislation and practices to mitigate environmental impact including waste management and recycling.

Note regarding delivery of this unit: This unit has been designed to consider the use of materials across a range of manufacturing sectors, including, but not limited to, the automotive, food and drink, and textile manufacturing industries. The *Essential Content* section has been designed to be intentionally broad; however it is for individual Centres to focus on the relevant material types for a particular manufacturing sector. The use of e.g. within the *Essential Content* allows for Centres to select and focus on particular areas of delivery.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate material sources in terms of their sustainability and environmental impact

LO2 Explore the energy resources currently available and the potential of renewable energy as an alternative to traditional sources

LO3 Explore the rise in consumerism, what drives it and its impact on society and the environment

LO4 Justify the design for a sustainable product in terms of its manufacture, finishing, working life and post-life disassembly, recycling or repurposing.

Essential Content

LO1 Investigate material sources in terms of their sustainability and environmental impact

Source material from a range of sectors, including crops utilised as raw material for industry, e.g.:

Wood for paper and similar products, cotton for textiles, linen, silk, rubber, leather, biomaterials for plastics, biomass for fuel, coir, hemp, cereals /vegetables/fruits/nuts and other products for the food industry.

Mined materials, e.g.:

Salt, minerals and ores, coal, oil and gas, clays, potash (for fertiliser).

Animal husbandry:

Rearing of animals and their impact on the environment

Depletion of pasture lands as a result of monocultures for livestock feed

Methane emissions from animal husbandry

Environmental impact of leather processing.

Other factors to consider:

Analysis of resources and reserves using McKelvey Diagrams

Water usage

Land use/overuse and the acquisition of virgin land; changes in land use (switching of crops e.g. rubber trees to palm oil production); salinisation of land

Carbon footprint in the production and delivery of materials

Seasonality

Conversion of raw material to a state required by industry (e.g. ore to metal, wheat to flour) considering aspects such as energy and water demands.

LO2 **Explore the energy resources currently available and the potential of renewable energy as an alternative to traditional sources**

Traditional resources, including gas and oil, coal and nuclear, looking at:

Impact of extraction from its source for conversion into usable energy

Resultant emissions, and implications for whether sustainable

Water and land usage

Safety aspects including disposal of waste products.

Renewable resources, including hydroelectric, tidal, geothermal, ocean energy, biomass, bio-methane, solar, wind, wood and/or waste incineration, looking at:

Water usage

Land usage

Emissions

Sustainability and consistency of supply.

LO3 **Explore the rise in consumerism, what drives it and its impact on society and the environment.**

Consumer items, e.g.:

automobiles, clothing, white goods, food items, leisure equipment.

Economic materialism:

impact of business models based on over-consumption (e.g. buy-one-get-one-free/BOGOF); impact of growth-based economic models on the environment; consideration of different economic models and their potentially different impacts.

Overproduction:

causes of, and incentives for, overproduction; role of cost and price factors in overproduction; approaches that could ensure production is tailored and limited to need.

Single-use products:

most often referring to plastics but can relate to other materials such as aluminium foil or foiled/waxed cardboard; typical items include drinks bottles and cartons (paper/plastic), coffee cups (paper/plastic), food cans; technologies for producing lower-impact, disposable or biodegradable single-use products.

Imparting desirability to a product through the use of such devices as:

advertising, psychology, price strategies.

Factory waste, over-production and rejects/by-products, e.g.:

the destruction of garments that are deemed out of season; food products rejected when past best-before or sell-by date; scrap material formed during manufacture (e.g. runners/sprues in plastic production or risers in metal casting), metallic swarf from machining operations.

LO4 **Justify the design for a sustainable product in terms of its manufacture, finishing, working life and post-life disassembly, recycling or repurposing.**

Techniques or practices, e.g.:

conducting due diligence with respect to ethical practice when contracting suppliers; lean practice in operations, packaging and logistics, to reduce waste and carbon footprint; looking at life cycles of products and processes to create circular systems that redeploy by-products.

Paradigm shifts in production, e.g.:

the introduction of electric cars, bio-buses, solar recharging devices.

Designing to avoid waste:

lean practices to improve efficiency; strategic planning to meet demand without overproduction; looking at whole life cycle of a product, including end-of-life disposal; closing the circle so that materials can return to the system.

Designing for sustainability such as:

products manufactured with a view to dis-assembly, recycling, remoulding, repurposing, repair.

Design to minimise energy use in terms of:

production, working life, maintenance, repair.

Disposal to avoid landfill or incineration, including:

use of materials that can be disassembled, repurposed and/or recycled.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate material sources in terms of their sustainability and environmental impact		**LO1 and LO2**
P1 Assess the availability of the raw material required for production. **P2** Explain the environmental impact in acquiring this material.	**M1** Report possible pitfalls in the continued use of this material.	**D1** Evaluate material and energy choices that appear vital in a given manufacturing process and suggest alternatives or ways of eliminating this process over time.
LO2 Explore the energy resources currently available and the potential of renewable energy as an alternative to traditional sources		
P3 Explain the energy requirements for a sector of the manufacturing industry. **P4** Outline alternative sources of energy for a sector in the manufacturing industry.	**M2** Analyse the viability and sustainability of the alternative sources cited, including factors such as assured supply, and contrast this with traditional energy sources.	
LO3 Explore the rise in consumerism, what drives it and its impact on society and the environment		
P5 Explore the means by which a product becomes a consumer item.	**M3** Analyse the drawbacks in pursuing consumerism in terms of sustainability and the environment.	**D2** Evaluate the impact of consumerism on the environment, taking the example of a single-use product, and show how society has responded.
LO4 Justify the design for a sustainable product in terms of its manufacture, finishing, working life and post-life disassembly, recycling or repurposing.		
P6 Redesign a product, identifying sustainable methods and materials. **P7** Outline the finishing, or other ancillary, processes required in this design and show how they can be considered sustainable or environmentally friendly.	**M4** Analyse the production, finishing and other ancillary processes specified for this design to show how they can be considered sustainable or environmentally friendly.	**D3** Evaluate operating environmental impact, operating energy, where applicable and end-of-life plan for selected product.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Andrews, J. and Jelley, N. (2017) *Energy Science: Principles, Technologies and Impacts*. 3rd Ed. Oxford: Oxford University Press.

Ashby M. F. (2021) *Materials and the Environment: Eco-informed Material Choice*. 3rd Ed. Butterworth-Heinemann.

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Ehrman, E. (2018) *Fashioned From Nature*. London: Victoria and Albert Museum.

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Gökan K. and dimitrios K. (2019) *Smart Sustainable Manufacturing Systems*. MDPI.

Hone, D. (2017) *Putting the Genie Back. Solving the Climate and Energy Dilemma*. Bingley: Emerald Publishing.

Websites

http://www.carbontrust.com	Carbon Trust Carbon footprinting (General reference)
sustainabledevelopment.un.org	United Nations Sustainable Development (General reference)
sustainablefoodtrust.org	Sustainable Food Trust What to read in 2018? (Article)

http://www.unwater.org	United Nations Annual World Water Development Report (Report)
http://www.populationinstitute.org	Population Institute Demographic Vulnerability report Annual World Water Development Report (Report)
http://www.cat.org.uk	Centre for Alternative Technology Sustainable technologies including construction and land use (Report)
http://www.gov.uk	UK Gov Department of Energy and Climate Change (General reference)
http://www.eauc.org.uk	The Environmental Association for Universities and Colleges (EAUC)/Sustainability Exchange – advice for higher education providers on sustainability (General reference)
sustainabilityexchange.ac.uk	Sustainability Exchange (General reference)
heacademy.ac.uk	Advance HE Education for sustainable development: Guidance for UK higher education providers (Guidance document)
https://www.theguardian.com	The Guardian Renewable energy (Articles)

Links

This unit links to the following related units:

Unit 4017: Quality and Process Improvement

Unit 4069: Properties and Applications of Materials and Emerging Materials pre-Production

Unit 4076: Manufacturing Processes

Unit 4077: Lean Techniques for Manufacturing Operations.

Unit 4074: Workplace Study and Ergonomics

Unit code H/617/3927

Unit level 4

Credit value 15

Introduction

The aim of this unit is to develop students' ability to identify and carry out productivity measurement and improvement, ergonomic and plant layout design and work measurement and method study. Understanding the workplace is an important part of any manufacturing operation. Being able to review the processes involved, identify the influencing factors and then review and improve these allows future manufacturing operation to develop and maximise productivity, improve quality and use resources in the most efficient way.

Students will apply several lean manufacturing techniques commonly used to identify and eliminate waste within manufacturing and production environments. Within the unit students will look at real or simulated manufacturing environments and have the opportunity to apply and see skills and techniques at work.

On successful completion of this unit students will be able to analyse manufacturing situations, identify areas for improvement and apply techniques to demonstrate how changes made would improve the productivity of the process, and/or the layout or physical ergonomics of the workplace, and present this information in a suitable format.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate productivity measurement techniques and the effect of a range of improvement methods

LO2 Review the features of work measurement and method study techniques

LO3 Assess the ergonomic and layout planning features of workstation and manufacturing operations design

LO4 Apply industrial engineering techniques to a given engineering/manufacturing situation.

Essential Content

LO1 Investigate productivity measurement techniques and the effect of a range of improvement methods

Productivity measurement:

Methods of measuring physical factors – labour, materials and equipment; single factor and integrated productivity measurement, critical analysis techniques including cost‒benefit analysis and force field analysis

Evaluation may include graphical representations, statistical representations, fitness for purpose considerations and recognition of short-term and long-term effects – e.g. quality, cost, delivery (QCD) metrics; value stream mapping (VSM); process mapping.

Productivity improvement:

Reduction in unit cost of manufacture in terms of labour, product, materials, production level or machine automation

Uses of new technology

Efficient manual operation – taking account of work-study; job design; layout and ergonomic design; total quality management (TQM) methods

Reduction in waste of resources (e.g. energy, staff time, materials) – reduction/elimination of the 'eight wastes'; standardised operations and their relevant forms; takt time analysis and production smoothing; change-over analysis, single-minute exchange of dies (SMED).

LO2 Review the features of work measurement and method study techniques

Work measurement:

Direct work measurement – time study and activity sampling

Indirect work measurement – synthetic timing

Predetermined motion time systems (PMTS) – methods time measurement (MTM)

Computer-based programs

Primary standard data

Analytical estimating.

Method study:

Job selection

Recording methods and procedures

Method description

Development of improved method

Definition of new method and installation and maintenance.

Work measurement and study:

Chart format

Simple comparisons

Critical analysis

Ranking techniques

Technique application description

Fitness for purpose.

LO3 **Assess the ergonomic and layout planning features of workstation and manufacturing operations design**

Ergonomic features:

Features of design including worker machine controls

Environmental factors and anthropometrical data used in the design of workstations

Awareness of special features for VDU operators

Role of Health and Safety.

Layout planning features:

Features of design including types of layout

Operation sequence analysis

Layout planning procedures and methods.

Layout design:

Workstation design features such as characteristics of the operator

Interaction between workspace and the operator (e.g. posture, reach, desk/machine size, adjacent machinery, interaction between the environment and the operator).

Assessment techniques:

Develop criteria for good layout of workstation and manufacturing operations

Consider how multiple factors influence the final layout (e.g. flexibility, coordination, volume, visibility, accessibility, distance, handling, discomfort, safety, security, material flow, part identification, *poka yoke* and *jidoka* techniques).

LO4 **Apply industrial engineering techniques to a given engineering/ manufacturing situation.**

Engineering/manufacturing situation:

Collect information and data on current company aims (e.g. current productivity, measurement, processes, process flow, scheduling, materials, equipment, labour, layout, ergonomic features of labour force and equipment operation)

Present evidence in a relevant form (e.g. graphs, statistics, manuals, diagrams, recorded interviews, recorded observations, computer programs).

Engineering techniques:

Selection and application of techniques (e.g. productivity measurement, productivity improvement, method study, work measurement, ergonomic design, layout planning)

Formulate a plan of action

Appraise the feasibility of the techniques with reference to the engineering/manufacturing situation

Make simple comparisons and use decision-making techniques (e.g. consider fitness for purpose

Long-term and short-term effects on the engineering/manufacturing situation)

Record and justify any changes to current engineering/manufacturing situation

Present findings using relevant methods (e.g. use of graphs, statistics, flow diagrams, layouts, computer programs, graphical techniques, video, file, written reports and technical discussion)

Use appropriate lean manufacturing techniques (e.g. quality, cost, delivery (QCD) metrics, value stream mapping (VSM), process mapping, takt time analysis, production smoothing, pull systems, single-minute exchange of dies (SMED), visual management techniques).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate productivity measurement techniques and the effect of a range of improvement methods		
P1 Describe techniques of productivity measurement. **P2** Describe methods of productivity improvement.	**M1** Analyse the usefulness of the range of productivity measurement techniques and productivity improvement methods. **M2** Compare the use of productivity measurement techniques and productivity improvement methods and how these are linked.	**D1** Evaluate the impact and use of productivity measurement and improvement methods.
LO2 Review the features of work measurement and method study techniques		
P3 Explain how work study comprises work measurement and method study techniques. **P4** Describe situations for different uses of work measurement and method study techniques.	**M3** Analyse a range of work measurement and work study techniques used for a given situation.	**D2** Evaluate the use of data within work studies and the impact of using the correct formats for presenting information.

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Assess the ergonomic and layout planning features of workstation and manufacturing operations design</td><td rowspan="4">LO3 and LO4

D3 Design a hypothetical manufacturing layout showing how progression and development has been undertaken to arrive at a final proposal.</td></tr>
<tr><td>P5 Describe ergonomic and layout planning features of workstation and manufacturing operations design.</td><td>M4 Illustrate how features can be used to support operators and to develop criteria for good layout design.</td></tr>
<tr><td colspan="2">LO4 Apply industrial engineering techniques to a given engineering/manufacturing situation.</td></tr>
<tr><td>P6 Outline how industrial engineering techniques are selected to analyse a given engineering/manufacturing situation.

P7 Present relevant information/data from a given engineering/ manufacturing situation.</td><td>M5 Apply industrial engineering techniques to a given engineering/ manufacturing situation and summarise the impact of the improvements.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Burke, R. (2013) *Project Management, Planning & Control Techniques*. 5th Ed. Chichester: John Wiley & Sons.

Singh P. L. (2015) *Work Study and Ergonomics*. Cambridge University Press.

Stroud, K.A. and Booth, D.J. (2013) *Engineering Mathematics*. 7th Ed. Basingstoke: Palgrave Macmillan.

Tewari P.C. (2018) *Work Study and Ergonomics.* CRC Press.

Tooley, M., and L Dingle (2012) *Engineering Science: For Foundation Degree and Higher National*. London: Routledge.

Other resources

Many of the techniques involved in industrial engineering use specialist software that may prove expensive. In such cases, Centres will need to ensure that students can view an industrial demonstration of such software at the least.

Links

This unit links to the following related units:

Unit 4030: Industry 4.0

Unit 4076: Manufacturing Process

Unit 4078: Manufacturing Planning and Scheduling Principles

Unit 4079: Manufacturing Operations Mathematics

Unit 4080: Business Improvement Techniques for Engineers.

Unit 4075: Business Improvement Techniques for Engineers

Unit code	**K/617/3928**
Unit level	**4**
Credit value	**15**

Introduction

The quality of the output from any business is the key to its success and profitability.

To achieve the highest possible quality at the minimum cost of materials, processes and time, most businesses employ some form of Quality Assurance or business improvement process. These systems are usually company-wide philosophies and practices designed to bring about improvements to the business at all levels.

This unit introduces students to the importance of quality improvement and assurance processes and the principles that underpin them, both to the business and to its customers. The most important continuous improvement processes will be introduced and their applications detailed. In particular, the Six-Sigma methodology will be studied together with an introduction to the application of failure mode and effect analysis techniques and measurement systems analysis. Practical experience of the application of the Six-Sigma system will be undertaken.

On successful completion of this unit the student will be able to explain the development, importance and principles of quality improvement within a business structure, including providing an outline of the most important systems and cost-effective quality practices. They will be able to describe the Six-Sigma methodology in detail and explain the role played by failure mode and effect analysis. The use of worksheets for mistake/error proofing activities will also be considered.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the importance of quality improvement processes to a business

LO2 Compare the most commonly used continuous business improvement principles and techniques

LO3 Examine the origins and key factors of Six-Sigma methodology

LO4 Apply potential failure modes and effects analysis and create worksheets of mistake/error proofing activities.

Essential Content

LO1 Explain the importance of quality improvement processes to a business

Quality:

The importance of quality to companies and customers

How quality underpins a company's ability to improve efficiency, competitiveness and profitability

The role of standards in improving quality

National, European and international standards.

Quality improvement processes:

The need for logical and progressive processes to examine, check and improve quality

Quality strategies

Local and company-wide quality improvement processes

The success of whole-company quality philosophies worldwide

Attitudes and approaches to the implementation of company-wide (total quality commitment) quality improvement processes

Supply chain considerations.

LO2 Compare the most commonly used continuous business improvement principles and techniques

Continuous improvement processes:

Statistical process control (SPC)

Optimised production technology (OPT)

Total productive maintenance (TPM)

Total quality management (TQM)

Six-Sigma; Lean; Six-Sigma Lean.

Continuous Improvement terms and techniques:

Organisational policy and procedures

Quality circles

Production of key performance indicators

Kaizen, Hansel (self-reflection).

Charts and diagrams:

Cause-and-effect diagrams

Check sheets

Control charts

Histograms

Pareto charts

Scatter diagrams

Stratification.

LO3 **Examine the origins and key factors of Six-Sigma methodology**

Origins of Six Sigma:

Origination and development at Motorola, USA in 1980s, from statistical modelling of manufacturing processes

Roles of Mikel Harry, Bob Galvin and Bill Smith at Motorola

Development at General Electric and Honeywell

Six Sigma as a way of doing business.

Six Sigma methodology:

Six Sigma as a disciplined, data-driven way of eliminating defects in any process or part of that process

Relationship between mean value and nearest specification limit (six standard deviations)

Key principles: customer-focused; the value stream (how work is done) − manage, improve and smooth work process flow, remove processes that add no value (eliminate waste), manage process by fact (measurement) to reduce variation, involve and train staff at all levels, undertake improvements in a systematic way.

LO4 **Apply potential failure modes and effects analysis and create worksheets of mistake/error proofing activities.**

Failure mode and effect analysis (FEMA):

Systematic study of actual or predicted component failure(s) in a design, manufacturing or assembly process and the consequences of such failures (types of failure include component failure, human error in a process)

When to use FEMA: during design or redesign, change of use of component, when modifying manufacturing or assembly process, when analysing in-service failures, during scheduled checking.

Failure/mistakes/error mode proofing worksheets:

Worksheets to record component function, potential failure mode, potential effects of failure, containment plan, potential causes of failure, existing process controls to prevent failure, recommended action, costs and timescales

Use of worksheets to improve quality.

Lessons learnt:

What went well and how to recreate success

Avoiding repetition of past mistakes

Performance improvement on future projects

Commercial impact.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the importance of quality improvement processes to a business		
P1 Illustrate the importance of quality to a manufacturing organisation. **P2** Explore the role of standards in quality improvement.	**M1** Analyse how quality improvement can be implemented in a manufacturing setting.	**D1** Evaluate the effectiveness of the introduction/use of a company-wide quality programme.
LO2 Compare the most commonly used continuous business improvement principles and techniques		
P3 Identify the most commonly used continuous business improvement principles and techniques. **P4** Identify the differences between operationally specific quality processes and company-wide processes.	**M2** Assess the way in which self-reflection is at the heart of any continuous improvement process.	**D2** Evaluate how data is used to drive continuous improvement processes.
LO3 Examine the origins and key factors of Six-Sigma methodology		
P5 Explain how Six Sigma was developed from earlier statistical modelling techniques. **P6** Define the most important elements of the Six-Sigma methodology.	**M3** Analyse how standard deviation plays a major part in the Six-Sigma methodology.	**D3** Evaluate how Six-Sigma can be employed to improve a given manufacturing process.
LO4 Apply potential failure modes and effects analysis and create worksheets of mistake/error proofing activities.		
P7 Describe the types of failure that can be analysed using failure mode and effect analysis (FEMA). **P8** Review the conditions when the use of failure mode and effect analysis (FEMA) is appropriate in a manufacturing process.	**M4** Produce a failure mode worksheet for use in a failure analysis evaluation.	**D3** Evaluate how Six-Sigma can be employed to improve a given manufacturing process.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Oakland, J.S. (2013) *Total Quality Management: Text with Cases*. 3rd Ed.
Oxford: Butterworth-Heinemann.

Pyzdek, T. and Keller, P. (2018) *The Six Sigma Handbook*. 5th Ed. New York: McGraw-Hill.

Websites

http://www.asq.org	American Society for Quality (General reference)

Links

This unit links to the following related units:

Unit 4017: Quality and Process Improvement

Unit 4030: Industry 4.0

Unit 4074: Workplace Study and Ergonomics

Unit 4077: Lean Techniques for Manufacturing Operations.

Unit 4076: Manufacturing Processes

Unit code	**F/617/3918**
Unit level	**4**
Credit value	**15**

Introduction

Cars, food and drink, textiles, electronic and household appliances are manufactured using a variety of processes and materials. These processes have several interdependent stages, and producing finished high quality products at competitive prices requires that each part of the process operates efficiently.

This unit introduces students to the various processes and technologies used in the manufacture of products. It covers the various stages in the manufacture of a product including: energy consumption, environmental impacts, and the selection of appropriate operations. Also included are the materials and methods that may be used.

On successful completion of this unit the student will be able to identify the fundamental methods and stages in product manufacture within their industry. Students will have the opportunity to investigate some, or a combination of, particular operations including manual and automated systems, fixed-time sequential systems, batch operations requiring inventory transfer and lead time, flow and bulk transfer and chemical and thermal processes in which a change of state occur. Students will also be able to describe how sustainability considerations, for example, energy consumption or environmental impact, are an essential part of the manufacturing process.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate pre-manufacturing supply chain processes

LO2 Review processes used to manufacture products

LO3 Define manufacturing systems by product type

LO4 Describe the post-manufacturing supply chain process.

Essential Content

LO1 **Investigate pre-manufacturing supply chain processes**

Supply chain relationship and management:

Purchasing and supply systems

Quality assurance, control of raw materials, goods inward

Safe handling, storage and distribution of parts and raw materials to the process

Effectiveness of pre-manufacturing supply chain processes in terms of cost, sustainability, Health and Safety, quality and productivity.

LO2 **Review processes used to manufacture products**

Types of manufacturing process:

Processing technologies

Automation

Chemical and thermal processes

Separation and extraction methods

Fabrication

Material shaping and removal

Additive processes

Joining and assembly.

Material handling and storage systems:

Manual handling

Automated handling

Conveyor systems

Pumping

Storage.

Manufacturing process characteristics:

Selection

Capability including surface finish

Tolerances

Volume and variety and effects on manufacturing costs, efficiencies, process changeovers/set up

Health and safety.

Quality systems:

Quality control

Product defects and causes

Lean processes

Kanban/just in time (jit).

Sustainability:

Selection of materials

By-product and waste disposal

Minimisation of waste from packaging, scrap, and by-products

Rework/scrappage

Recycled materials and implications on products and processes

Environmental impacts including the need to reduce usage of energy and water

Corporate image

Legislation and regulatory requirements

Energy consumed

Carbon footprint.

LO3 **Define manufacturing systems by product type**

Selection of manufacturing process:

Sequential fixed-cycle operations

Batch operations with inventory transfer and lead time

Flow and bulk transfer

Chemical and thermal operations involving a change of state.

Manufacturing cycle:

Impact on upstream and downstream processes.

Design and layout of the overall production system:

Production volume, automation, manual production

Production strategies, scale of investment, embedded investments.

LO4 **Describe the post-manufacturing supply chain process.**

Finished product:

Supply chain process

Shipping of finished products

Distribution system.

Handling and storage methods:

Packaging

Containers

Final quality assurance

Acceptable quality levels

Defect detection

Distribution system.

Management of finished products; quality assurance methods:

End user

Client relationship

Corporate image.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate pre-manufacturing supply chain processes		
P1 Investigate the supply chain processes used to provide components and raw materials to the manufacturing process. **P2** Explain the function of the purchasing, quality assurance and goods inwards departments in relation to the supply of components and raw materials.	**M1** Analyse how the acquisition and quality of raw materials and components is controlled.	**D1** Evaluate how the timely supply and quality of components and raw materials impact upon the manufacturing process.
LO2 Review processes used to manufacture products		
P3 Review the manufacturing processes that safely manufacture multi-part products. **P4** Review the materials handling and storage systems used in the manufacture of multi-part products.	**M2** Analyse the suitability of the manufacturing processes and materials handling and storage methods selected to safely manufacture a given multi-part product.	**D2** Justify the processes and methods selected to manufacture the given multi-part product in terms of sustainability.

Pass	Merit	Distinction
LO3 Define manufacturing systems by product type		**D3** Evaluate how production strategies for high, medium and low volume production may be influenced by the scale of investment.
P5 Explain how the nature of the product determines the selection of a particular manufacturing process. **P6** Define how manufacturing processes influence the layout of the overall production system.	**M3** Analyse how production volume influences the selection of manufacturing process and layout.	
LO4 Describe the post-manufacturing supply chain process.		**D4** Evaluate how quality assurance methods, storing and shipping of finished products impact on corporate image/reputation.
P7 Investigate the supply chain processes used to provide finished products to customers. **P8** Describe the handling and storage of finished goods.	**M4** Analyse finished product quality management processes.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Black, J.T. and Kohsher, R.A. (2017) *Degarmo's Materials and Processes in Manufacturing.* 12th Ed. New Jersey: Wiley.

Brunt D. (2010) *Manufacturing Operations and Supply Chain Management*. Cengage Learning.

Fellows, P.J. (2017) *Food Processing Technology Principles and Practice*. 4th Ed. Cambridge: Woodhead Publishing.

Huang Y., Wang L. and Liang S.Y. (2019) *Handbook of Manufacturing.* World Scientific Publishing Company.

Kaushish, J.P. (2010) *Manufacturing Processes*. 2nd Ed. New Delhi: PHI Learning.

Kazmer, D. (2009) *Plastics Manufacturing Systems Engineering.* Munich: Hanser Publications.

Strong, A.B. (2008) *Fundamentals of Composites Manufacturing Materials, Methods and Applications.* 2nd Ed. Michigan: Society of Manufacturing Engineers.

Websites

http://www.engineershandbook.com	Engineer's Handbook Manufacturing Processes (General reference)
http://www.thelibraryofmanufacturing.com	The Library of Manufacturing (General reference)
http://www.hitachirail-eu.com	SlideShare Garment manufacturing process from fabric to poduct (General reference)

Links

This unit links to the following related units:

Unit 4078: Manufacturing Planning and Scheduling Principles

Unit 4080: Material Handling Systems

Unit 4083: Creating and Managing Projects in Manufacturing Operations

Unit 4086: Introduction to Manufacturing Systems Engineering

Unit 5073: Sustainability and the Environment in the Manufacturing Industry.

Unit 4077: Lean Techniques for Manufacturing Operations

Unit code	**H/617/3930**
Unit level	**4**
Credit value	**15**

Introduction

Lean manufacturing is a systematic approach to minimising waste in manufacturing operations. The 'lean' approach originated in the car industry and was developed by Toyota in Japan. Lean is now used extensively worldwide, in all types and size of organisation, to improve efficiency and competitiveness.

The aim of this unit is to introduce students to the basic principles and applications of lean manufacturing, so that they can become effective and committed practitioners of lean in whichever sector they work. To do this, the unit will explore the tools and techniques that are applied by organisations practising lean. The students will consider both the benefits and the challenges of using lean, so that they will develop sufficient knowledge about the most important process tools, techniques and applications to be able to operate and use them.

The topics included in this unit are: scoping and defining lean manufacturing; the benefits and challenges of adopting lean; the Toyota Production System (TPS), and other systems; common tools and techniques associated with lean manufacturing and process improvement; and the most appropriate improvement tool(s) to tackle a problem.

On successful completion of this unit, students will be able to explain the origins and common principles of lean manufacturing and utilise a range of the process improvement tools used within lean manufacturing, demonstrating communication skills that will enable them to participate effectively in the process of continuous improvement in the workplace.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the common principles of lean manufacturing and how the implementation of a lean production system contributes to workplace efficiency

LO2 Explore the most widely used approaches to lean manufacturing

LO3 Review a range of the process improvement tools used within lean manufacturing

LO4 Communicate the challenges and benefit of lean techniques in the workplace.

Essential Content

LO1 **Describe the common principles of lean manufacturing and how the implementation of a lean production system contributes to workplace efficiency**

Describing and defining lean manufacturing:

Manufacturing processes in the immediate post-Second World War period

Origins of lean manufacturing: the need for improved manufacturing processes to improve output, quality and reliability, and reduce costs.

Common principles of lean manufacturing philosophy:

Importance of lean manufacturing to the company, employee, customer

Identification/elimination of material and process wastes that add no value to the final output

Audit of processes, material selection, form, supply, storage, transportation of materials and finished products, plant layout and human factors.

Benefits and challenges of adopting lean:

Reasons an organisation might consider adopting a lean approach to their operations: failing sales and profitability, poor competitiveness, quality and reliability issues, disengaged workforce

Productivity, quality, customer satisfaction, delivery performance in a lean context

The benefits of a lean organisation to the customer, the company and the employees

Challenges and costs of lean implementation: change management, managing expectation, empowerment, motivation, investment and supply chain involvement.

LO2 **Explore the most widely used approaches to lean manufacturing**

Toyota Production System (TPS):

Motivation behind the TPS; the importance of manufacturing to post-Second World War Japan, making Japanese manufacturing more competitive

Fundamental elements of the TPS; complete elimination of waste of all kinds; Jidoka – 'automation with a human touch'; highlighting and visualisation of problems, preventing defective or sub-standard components being produced

Just-in-time.

Other quality systems:

Total quality management (TQM), Six Sigma, production systems publicised by other global manufacturers

Adoption of lean manufacturing principles outside manufacturing, e.g. banking, service sector.

LO3 Review a range of the process improvement tools used within lean manufacturing

Common tools associated with lean manufacturing and process improvement:

Seven Wastes, continuous flow, Kanban (pull system), just-in-time (JIT), lean simulation activities, value stream mapping, poka-yoke, 5 Whys (root cause analysis), total preventative maintenance (TPM)

Plan-do-check-act (PDCA), single minute exchange of die (SMED), A3 reporting, visual management

Tools for improving quality and delivery, selecting the most appropriate improvement tool to tackle a problem.

LO4 Communicate the challenges and benefit of lean techniques in the workplace.

Communication:

Role and importance of continuous, open communication at all levels in the effective application of lean approaches: accepting change as the norm, reporting and commenting at all levels, treating information as the key to improvement

Role of the small work group in implementing lean principles: how regular and effective meetings can identify local problems, solutions and more general improvements

Factors that influence engagement within a group: honesty, common goals, allowing all members to contribute, valuing contributions equally, listening, keeping focused, effective questioning and non-aggressive responses, importance of keeping to time and timely feedback.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the common principles of lean manufacturing and how the implementation of a lean production system contributes to workplace efficiency		
P1 Describe how lean manufacturing principles can improve company efficiency and product performance. **P2** Specify the role of the employee in the lean manufacturing process.	**M1** Justify the benefits of adopting lean principles in a manufacturing operation.	**D1** Evaluate the main challenges facing a company adopting lean operating principles for the first time.
LO2 Explore the most widely used approaches to lean manufacturing		
P3 Explain why Toyota developed the Toyota Production System (TPS). **P4** Detail the underpinning principles of the TPS. **P5** Explore other lean production systems to compare with the TPS.	**M2** Analyse alternative lean manufacturing processes to illustrate how they build on the TPS.	**D2** Illustrate how TPS can be modified to suit a specified process environment.
LO3 Review a range of the process improvement tools used within lean manufacturing		
P6 Review the most important process improvement tools associated with lean manufacturing.	**M3** Analyse how process improvement tools can be used to eliminate waste in a specified manufacturing process.	**D3** Evaluate a lean tool to be applied to address a specific process improvement.
LO4 Communicate the challenges and benefit of lean techniques in the workplace.		
P7 Outline why communication skills are so important in the implementation of lean principles. **P8** Specify the particular communications skills required to ensure effective small group work.	**M4** Analyse how good communication skills can reduce the impact on individuals and organisations facing change.	**D4** Evaluate the communication requirements for a medium-sized company adopting lean processes across all aspects of their manufacturing operations.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Baudin M. and Netland T. (2023) *Introduction to Manufacturing: An Industrial Engineering and Management Perspective*. Taylor & Francis.

Bicheno, J. and Holweg, M. (2009) *The Lean Toolbox*. 4th Ed. PICSIE Books.

Fast E. L (2016) *The 12 Principles of Manufacturing Excellence*. 2nd Ed, CRC Press.

Liker, J. and Meier, D. (2006) *The Toyota Way Fieldbook*. New York: McGraw-Hill.

Wang X. J. (2011) *Lean manufacturing: business bottom-line based*. Taylor & Francis.

Womack, J., Jones, D. and Roos, D. (1990) *The Machine that Changed the World*.
New York: Free Press.

Websites

lean-manufacturing-japan.com	Lean Manufacturing Japan (General reference)
http://www.lean.org	Lean Enterprise Institute (General reference)
http://www.leanmanufacturingtools.org	Lean Manufacturing Tools (General reference)
http://www.leanproduction.com	Lean Production (General reference)

Links

This unit links to the following related units:

Unit 4017: Quality and Process Improvement

Unit 4073: Sustainability and the Environment in the Manufacturing Industry

Unit 4086: Introduction to Manufacturing Systems Engineering.

Unit 4078: Manufacturing Planning and Scheduling Principles

Unit code A/617/3920

Unit level 4

Credit value 15

Introduction

Planning is an essential skill for all engineers. The manufacturing industry demands an efficient and effective approach to high volume production to ensure costs are minimised and potential problems identified and solved quickly. This unit will develop students' understanding of the methodologies and techniques that are used in process planning and scheduling and will enable them to plan and schedule a manufacturing activity.

Students will develop an understanding of how manufactured products and their associated processes are planned, monitored and controlled and extend their knowledge of, and ability to apply, both manual and computer-assisted methods and procedures.

The unit covers process plans (for example forecasting, network analysis, etc.), capacity assessment and scheduling. This leads into inventory management, with stock control and documentation systems being an important element.

On successful completion of this unit students will be able to explain the techniques used to plan manufacturing and scheduling activities. The skills developed will allow the student to consider alternative approaches and choose the most effective method to achieve efficient production.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Review methods of process planning and capacity assessment of manufacturing processes

LO2 Outline techniques of inventory management, stock control, use of documentation control systems

LO3 Demonstrate methods to classify and code component parts as key elements of group technology and efficient production

LO4 Plan and schedule a manufacturing activity.

Essential Content

LO1 **Review methods of process planning and capacity assessment of manufacturing processes**

Process planning:

Forecasting

Network analysis

Critical path method (CPM)

Project evaluation and review technique (PERT)

Material requirement planning (MRP II)

Make or buy decisions

Computer-aided planning and estimating

Enterprise resource planning (ERP).

Capacity requirements planning (CRP):

Bill of materials (BOM)

Economic batch size

Availability of labour

Equipment and tooling

Methods of increasing/decreasing capacity and time standards.

LO2 **Outline techniques of inventory management, stock control, use of documentation control systems**

Materials and manufacturing processes:

Better utilisation of raw materials and energy

Integration of design and manufacturing activities

Introduction of new processes and techniques

Unmanned production/intelligent processing

Introduction of new materials

New manufacturing process technology.

Inventory management:

Types of inventory

Dependent and independent demand

Buffer stock

Cost of inventory.

Stock control systems:

Periodic review

Re-order points

Two-bin system

Basic economic order quantities (EOQ)

Kanban/Just In Time (JIT).

Documentation controls:

Flow processes

Work orders

Routine documentation

Job tickets

Finished quantities

Rework and scrap

Stock records.

Shop control:

Release of works orders

Work in progress (WIP)

Quality checks and inspection

Data collection and feedback.

LO3 **Demonstrate methods to classify and code component parts as key elements of group technology and efficient production**

Classifying and coding:

Sequential

Product

Production

Design

Opitz method

Classification of parts into families for efficient mass production.

Grouped facilities:

Layout

Product

Process

Fixed position

Flexibility

Grouping and sequencing of facilities of parts to minimise delays

Material handling.

LO4 **Plan and schedule a manufacturing activity.**

Process plan:

Forecasting to identify timings and throughput

Provision of materials

Equipment and tooling

Methods and processes needed

Labour requirements

Inspection

Workmanship standards and quality checks

Data logging and use of computer-based systems.

Production schedule:

Process planning

Customer requirements

Lead times

Using scheduling techniques

CPM

Gantt charts

OPT

MRP II

Aided by software packages.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Review methods of process planning and capacity assessment of manufacturing processes		**LO1 and LO2**
P1 Explain different process planning techniques. **P2** Explain the use of capacity assessment for different types of manufacturing process.	**M1** Analyse different process planning techniques and capacity assessment for a given manufactured product.	**D1** Evaluate the processes necessary to ensure a given product is manufactured efficiently.
LO2 Outline techniques of inventory management, stock control, use of documentation control systems		
P3 Outline materials and manufacturing processes for a given manufactured product. **P4** Identify the critical elements of inventory management. **P5** Explain different shop floor documentation systems.	**M2** Show how materials and manufacturing processes support an inventory management system for a given manufactured product and how this would interface with a shop floor documentation system.	
LO3 Demonstrate methods to classify and code component parts as key elements of group technology and efficient production		**LO3 and LO4**
P6 Describe how component parts are classified into families for manufacturing purposes. **P7** Illustrate how shop floor layout is designed to maximise production of multi-part products.	**M3** Analyse how the classification of facilities of parts determines the layout and process flow of a given multi-part product.	**D2** Evaluate the process plan and production schedule for the efficient part delivery, layout, scheduling and manufacture of a given multi-part product.
LO4 Plan and schedule a manufacturing activity.		
P8 Produce a process plan for a given multi-part product. **P9** Produce a production schedule for a given multi-part product from its process plan.	**M4** Analyse the benefits of a process plan and production schedule for a given multi-part product.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Pinedo L. M. (2009) *Planning and Scheduling in Manufacturing and Services*. 2nd Ed. Springer.

Proud J. F. (2022) *Master scheduling: A practical guide to competitive manufacturing*. 5th Ed. Wiley.

Scallan P. (2023) *Process Planning: The Design/Manufacture Interface*. Elsevier.

Smith, R. and Wilson, J. (2010) *Planning and Scheduling Made Simple.* 3rd ed. Fort Meyers, Florida: Reliabilityweb.com.

Links

This unit links to the following related units:

Unit 4017: Quality and Process Improvement

Unit 4074: Workplace Study and Ergonomics

Unit 4075: Business Improvement Techniques for Engineers

Unit 4076 : Manufacturing Processes

Unit 4080: Material Handling Systems

Unit 4083: Creating and Managing Projects in Manufacturing Operations

Unit 4086: Introduction to Manufacturing Systems Engineering.

Unit 4079: Manufacturing Operations Mathematics

Unit code Y/617/3925

Unit level 4

Credit value 15

Introduction

Mathematics is an important discipline in many subjects: it supports decision making and problem solving within many sectors of engineering and business. It is essential that people working in the manufacturing industry, which is wide and varied, apply mathematics in the context of the manufacturing environment, for example to calculate how many parts or products would need to be manufactured to meet a customer's order, to measure and identify any weaknesses in a manufacturing process and to predict possible outcomes.

The mathematics delivered in this unit is directly applicable to the manufacturing sector. The unit will provide the opportunities to develop the necessary mathematical knowledge and understanding to support the broad underlying principles allied to the manufacturing industry.

Students will be introduced to the mathematical methods and techniques required to understand, analyse and solve problems within a manufacturing context. The importance of mathematics in this sector is crucial in ensuring the quality and repeatability of production. The exacting standards demanded require skilled personnel with a full appreciation of not only mathematical knowledge but the practical skills to measure, monitor and control processes within a manufacturing role.

On successful completion of this unit students will be able to apply mathematical methods within a variety of contextualised examples, interpret data from a variety of sources, such as tables, graphs and diagrams, including statistical and computational techniques to solve manufacturing problems. The student will be introduced to software packages such as Excel, Matlab, Autocad and Solidworks.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Develop arithmetic techniques to accurately measure and calculate component characteristics, production data and qualify standards of output

LO2 Apply a variety of statistical and probability techniques to interpret information and organise and present data

LO3 Investigate analytical and computer-based methods to help decision making in solving manufacturing problems

LO4 Plan and schedule a manufacturing activity.

Essential Content

LO1 **Develop arithmetic techniques to accurately measure and calculate component characteristics, production data and qualify standards of output**

Mathematical concepts:

Introduction to dimensional analysis and indices

Arithmetic and geometric progressions

Trigonometry

Standard units and derived units of measurement

Measurement techniques

Accuracy and inaccuracy

Precision, repeatability and reproducibility

Tolerances.

LO2 **Apply a variety of statistical and probability techniques to interpret information and organise and present data**

Data handling and statistical analysis:

Mean and median values

Standard deviation and variance

Graphical data analysis

Frequency distributions

Standard error of mean

Distribution of manufacturing tolerances.

Probability theory:

Gaussian distribution

Probability density function

Reliability.

LO3 **Investigate analytical and computer-based methods to help decision making in solving manufacturing problems**

Use of computers and data logging techniques to collect and assist in analysis of data, in costing and to apply quality control techniques:

Introduction to statistical process control (SPC)

To increase process improvement

Reduction of variability

Use of real-time data

Data plotting

Compliance with standards.

LO4 **Plan and schedule a manufacturing activity.**

Forecast timings and completion rate of manufacturing processes:

Identify the availability of materials and equipment needed for a given activity

Assess reliability of production techniques

Mean time to failure (MTTF)

Mean time to repair (MTTR)

Prediction of failure rates and effect of downtime on production schedules.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Develop arithmetic techniques to accurately measure and calculate component characteristics, production data and qualify standards of output		**LO1 and LO2** **D1** Evaluate the use of manufacturing and production data to support decision making.
P1 Develop arithmetic techniques to accurately measure components' characteristics. **P2** Calculate numerical problems using standard and derived units of measurement. **P3** Apply data to determine the accuracy and tolerances of manufactured parts.	**M1** Apply analytical techniques to solve contextualised problems in manufacturing.	
LO2 Apply a variety of statistical and probability techniques to interpret information and organise and present data		
P4 Summarise data by calculating mean and standard deviation of various manufactured products/parts. **P5** Calculate likely probabilities using frequency and Gaussian distributions of manufactured products.	**M2** Interpret the results of a statistical hypothesis test conducted from a manufacturing scenario.	

Pass	Merit	Distinction
LO3 Investigate analytical and computer-based methods to help decision making in solving manufacturing problems		**LO3 and LO4**
P6 Solve manufacturing problems using mathematical and computer-based methods. **P7** Present data accurately in a spreadsheet to identify trends and confirm the outcomes of a manufacturing activity.	**M3** Carry out calculations via a computer-based package to confirm the outcomes and support decision making.	**D2** Demonstrate a hypothetical manufacturing process (case study) and analyse the expected output against the probability of what may happen in a real manufacturing system.
LO4 Plan and schedule a manufacturing activity.		
P8 Explain how production forecasts are created and what may affect their accuracy. **P9** Illustrate how customer requirements are modelled mathematically to produce a workable production schedule, using a GANTT chart.	**M4** Produce a critical path analysis of the production of an engineering product.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Burke, R. (2013) *Project Management, Planning & Control Techniques*. 5th Ed. Chichester: John Wiley and Sons.

Sobot, R. (2022) *Engineering Mathematics by Example*. 1st Ed. Springer.

Stroud, K.A. and Booth, D.J. (2020) *Engineering Mathematics*. 8th Ed. Bloomsbury Publishing.

Urbano M. (2019) *Introductory Electrical Engineering with Math Explained in Accessible Language*. Wiley.

Vick B. (2020) *Applied Engineering Mathematics*. CRC Press.

Tooley, M. and Dingle L. (2012) *Engineering Science: For Foundation Degree and Higher National*. London: Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

http://www.elsevier.com	Elsevier
	Journal of Manufacturing Systems
	(Journal)
http://www.bluepenjournals.org	Blue Pen Journals
	Journal of Engineering and Manufacturing Technology
	(Journal)

Other resources

Centres will need to ensure students are able to have access the following software packages: Excel and MATLAB.

Awareness of other software packages such as Autocad and Solidworks would also be of benefit to the student.

Links

This unit links to the following related units:

Unit 4002: Engineering maths

Unit 4003: Engineering Science.

Unit 4080: Material Handling Systems

Unit code	**D/617/3926**
Unit level	**4**
Credit value	**15**

Introduction

Material handling is the movement of raw materials and partly or fully finished components/products within a manufacturing operation or between the operation and a method of transportation.

It employs a wide range of manual, semi-automated and automated equipment and includes consideration of the planning of the handling processes and the protection, storage, and control of the materials or components throughout their time in the manufacturing facility.

The unit introduces the student to the aims and strategies used in the logistics of material handling and the stages involved in the process. The criteria for the selection of material handling equipment will be explored as will the comparison of available systems using appropriate analysis tools. The planning, tracking and identification methods used, together with an analysis of their effectiveness, will also be covered.

On successful completion of this unit the student will be able to explain the principles of material handling and be able to plan and monitor operations and equipment and to analyse the effectiveness of the process.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the aims, strategies and logistics models used for material handling systems

LO2 Explain the operation of a range of material handling systems

LO3 Review the methods of control used in material handling systems

LO4 Undertake planning the layout of a material handling system.

Essential Content

LO1 Describe the aims, strategies and logistics models used for material handling systems

Aims of material handling systems:

Flow of materials; movement of work in progress, minimising cost of holding stock and maintaining high quality.

Stages of engineering material handling:

Selection and loading; moving and unloading; placement and positioning; materials including raw materials, components, sub-assemblies, parts, tools and consumables.

Strategies used:

Eliminate handling or movement; combine processing and movement; use automation or mechanical handling; use correct equipment in an appropriate manner; use unit loads, pallets and or containers to avoid mixing materials; practise economy of movement; recognise central authority and control of operation.

LO2 Explain the operation of a range of material handling systems

Criteria for the selection of a material handling system:

Industry-specific constraints, e.g. freshness, danger of contamination; location of material centres; material type and appropriate handling conditions; capital and resources available; future needs – expansion or contraction of operation; total cost of the handling system; compatibility with existing equipment and systems technologies.

Material handling systems:

Centrally coordinated and controlled systems; systems controlled by individual departments; automated and semi-automated systems.

Cost benefit analysis:

Benefits, e.g. reduced accidents and losses, increased capacity, speed, space, flexibility; ‘double handling’ bottlenecks and accidents; cost of designing, installing, staffing and maintaining.

LO3 **Review the methods of control used in material handling systems**

Control of material flow:

Computer-controlled networks; programmable logic controllers (PLCs); dedicated software; departmental control panels; automated storage and retrieval systems (ASRs); robots; radio-controlled vehicles; closed-circuit TV; advanced guided vehicles (AGVs) with on board computers.

Tracking and identification:

Voice recognition; coding systems; job tickets; radio-frequency identification (RFID); recording devices such as bar code readers, optical character recognition (OCR), numbers input manually. Identification devices such as optical sensors, proximity sensors.

Controlled material handling system:

Using material flow processes, dedicated or non-specialist material handling programmes to represent the control of a material handling system; detailed critical analysis of all decisions made; details of all critical control points; critical path network diagrams; other graphical communication techniques.

LO4 **Undertake planning the layout of a material handling system.**

Types of material handling equipment:

Cranes, lifts, vehicles, conveyors, pneumatic and hydraulic equipment, towing equipment, chutes, palletising systems, and robots.

Application of a range of equipment, e.g.:

Overhead, vertical, horizontal, horizontal fixed-route, horizontal non-fixed route equipment; speed of the equipment.

Factors influencing selection of material handling equipment, e.g.:

Features, size, weight, nature and volume of the materials; rate of movement required; route of movement; storage before and after movement; safety/hazards and concurrent processing.

Planning the layout:

Features of modern material handling systems

Detailed analysis of material movement needs, work-study and layout and planning techniques

Handling conditions required by the materials; requirements and constraints of the material handling system

Critical path analysis techniques

Gantt charts to determine key processes, procedures, sequence of events, equipment and time requirements

Technical and graphical techniques to illustrate final layout.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the aims, strategies and logistics models used for material handling systems		
P1 Review the aims of a typical manufacturing material handling system. **P2** Describe the stages of engineering material handling.	**M1** Analyse the strategies employed to achieve each stage of the material handling process.	**D1** Evaluate the effectiveness of the different strategies that might be employed to create a material handling system for a given application.
LO2 Explain the operation of a range of material handling systems		
P3 Detail the criteria used for the selection of a material handling system. **P4** Explain the main causes of bottlenecks in material handling systems.	**M2** Analyse the advantages and disadvantages of a centrally coordinated and controlled operation, compared with one controlled by individual departments.	**D2** Carry out a cost−benefit analysis by comparing two modern material handling systems.
LO3 Review the methods of control used in material handling systems		
P5 Review the methods used for the control of material flow in a material handling system. **P6** Explain the need for tracking and identification as part of a material handling system.	**M3** Analyse the effectiveness of a given process for the control of material flow.	**D3** Evaluate a controlled material handling system.
LO4 Undertake planning the layout of a material handling system.		
P7 Review the most important features of modern material handling systems. **P8** Assess the main Health and Safety concerns in a given material handling system.	**M4** Construct a layout of the proposed system using appropriate graphical techniques.	**D4** Evaluate the movements, conditions, requirements and constraints of the proposed material handling system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Rudd J. (2019) *A Practical Guide to Logistics: An Introduction to Transport, Warehousing,* Trade and Distribution. Kogan Pag.

Rudd J. (2020) *Health and Safety in Logistics: Assessing and Avoiding Risk in Warehousing and Transportation*. Kogan Page.

Pagano M. A. (2019) *Technology in Supply Chain Management and Logistics: Current Practice and Future Applications.* Elsevier.

Websites

http://www.warehousenews.co.uk	Warehouse News Warehouse and Logistics (General reference)

Links

This unit links to the following related units:

Unit 4018: Maintenance Engineering

Unit 4033: Programmable Logic Controllers (PLCs)

Unit 4068: Industrial Robots

Unit 4081: Monitoring and Fault Diagnosis of Engineering Systems

Unit 4084: Engineering Plant Operations and Maintenance

Unit 4085: Mechatronic Systems in Manufacturing.

Unit 4081: Monitoring and Fault Diagnosis of Engineering Systems

Unit code	**K/617/3931**
Unit level	**4**
Credit value	**15**

Introduction

This unit provides students with the opportunity to learn and apply a range of techniques to monitor and improve reliability, and diagnose faults, in engineering systems.

Engineering systems regularly use condition monitoring and quality control techniques to proactively detect symptoms of potential failure in engineering systems. The techniques used range from fully automated monitoring to human interpretation of system behaviour. The unit develops students' understanding of engineering system monitoring processes, fault diagnosis techniques and how digital techniques have improved quality control, reliability and responsiveness to environmental issues.

Health and Safety in the workplace is a serious matter and the unit gives students a clear understanding of the necessary precautions to be taken to protect themselves and others. The unit focuses on the safety measures needed when carrying out monitoring and fault-finding activities, especially those for isolation and protection.

Students will gain an understanding of condition monitoring equipment and the skills required to carry out systematic fault finding on engineering systems. They will develop the ability to select and set up monitoring equipment appropriate to the system being investigated. A variety of fault diagnosis and test techniques will be discussed. Students will learn how to use diagnostic aids to solve problems on the system under investigation.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Define Health and Safety requirements relevant to monitoring and fault diagnosis of engineering systems

LO2 Explain how system monitoring technology has been developed within engineering systems to improve quality and reliability of outputs

LO3 Outline a range of monitoring and test equipment within an engineering environment

LO4 Apply a range of fault diagnosis techniques to engineering systems.

Essential Content

LO1 **Define Health and Safety requirements relevant to monitoring and fault diagnosis of engineering systems**

Legislation:

Appropriate statutory acts and regulations in place, nationally and internationally.

UK regulations:

Health and Safety at Work Act, Management of Health and Safety Regulations, Provision and Use of Work Equipment Regulations (PUWER), Control of Substances Hazardous to Health (COSHH) Regulations, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR), Lifting Operations and Lifting Equipment Regulations, Manual Handling Operations Regulations, Personal Protective Equipment at Work Regulations, Confined Spaces Regulations, Electricity at Work Regulations, Control of Noise at Work Regulations, Health and Safety (First Aid) Regulations.

Health and Safety Organisations, e.g.:

British Safety Council, Health and Safety Executive, Health and Safety Authority, Institution of Occupational Safety and Health and Safety (IOSH); European Agency for Safety and Health at Work.

International standards:

ISO 45001 on Occupational Health and Safety Management Systems, managed by IOSH; International Labour Standards on Occupational Safety and Health, managed by the International Labour Organisation (ILO).

International/European regulations, e.g.:

European Union directives, e.g. Waste Electrical and Electronic Equipment (WEEE) directive, Restriction of Hazardous Substances (RoHS) directive.

Specific safety requirements, e.g.:

Company rules, permit to work procedures, risk assessments, environmental issues.

Health and Safety procedures, e.g.:

Response to alarms, use of safety equipment, reporting of accidents, reporting of hazardous items of plant or equipment.

Personal safety:

Appropriate dress, protective clothing, appropriate or protective headgear, protective gloves and footwear, eye protection, face masks and respirators, appropriate use of barrier creams, personal cleanliness, prompt attention to injuries.

Workplace Hazards, e.g.:

Compressed air, hydraulic fluid, gases, hot surfaces, electrical equipment, unfenced machinery, toxic substances and fumes, falling objects, liquid spillage, untidy work area, badly maintained tools and test equipment.

Safe working practices, e.g.:

Isolation procedures, methods of immobilising equipment, precautions to be observed when operating or working on live equipment, permit to work, use of danger tags, warning notices, safety barriers, cones and tapes.

Engineering systems:

Process monitoring and control; fault diagnosis; types of systems − mechanical, fluid power, electrical, process control, environmental systems (such as fume extraction or air conditioning).

LO2 **Explain how system monitoring technology has been developed within engineering systems to improve quality and reliability of outputs**

Monitoring terminology:

Condition monitoring methods, offline portable monitoring, sampled monitoring, continuous monitoring, protection monitoring, human sensory monitoring.

Monitoring techniques, including:

Vibration analysis, temperature analysis, flow analysis, particle analysis, crack detection, leak detection, pressure analysis, voltage/current analysis, thickness analysis, oil analysis, corrosion detection, environmental pollutant analysis.

Failure and reliability:

Calculations concerning failure, types of failure -catastrophic, intermittent and reduction in performance failures, causes of failure, failure rate, failure modes, functional failure, primary and secondary functions, mean time between failures (MTBF)

Reliability, factors affecting reliability

Aspects of design for failure/repair, operation, environment and manufacture, reduction in system/device failure, maintenance and routine servicing, adjustments; use of data in defects examination, statistical process control (SPC), Quality Assurance; confidence levels.

LO3 **Outline a range of monitoring and test equipment within an engineering environment**

Monitoring and test equipment:

Use of fixed and portable monitoring equipment for on and offline monitoring, including continuous and semi-continuous data recording, e.g.: vibration monitoring of bearings, self-diagnostics (such as PLCs/smart sensors, computerised data acquisition, data logging, electrical data, gas analysis)

Use of handheld instruments, e.g. meters, thermal imaging

Use of test equipment for taking measurements of parameters, e.g. temperature, pressure, viscosity, speed, flow, voltage, current, resistance, sound, vibration.

Procedures:

Non-destructive testing; practical methods, e.g. crack detection, leak detection, corrosion detection, flow analysis, vibration analysis, pressure analysis, X-ray.

LO4 **Apply a range of fault diagnosis techniques to engineering systems.**

Diagnostic terminology and techniques:

Terminology (definitions and explanations of symptoms, faults, fault location, fault diagnosis and cause); techniques such as six-point, half-split, input–output, emergent problem sequence, functional testing, injection and sampling, unit substitution.

Diagnostic aids:

Test and measuring equipment; other aids, e.g. plant personnel, manufacturers' manuals, system block diagrams, circuit and schematic diagrams, data sheets, flow charts, maintenance records/logs, self-diagnostics, software-based test and measurement, trouble-shooting guides.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Define Health and Safety requirements relevant to monitoring and fault diagnosis of engineering systems		
P1 Define the aspects of Health and Safety legislation that apply to monitoring and fault diagnosis of an engineering system. **P2** Describe the workplace hazards and safe working practices relevant to given fault diagnosis situations.	**M1** Analyse three statutory acts and regulations covering Health and Safety in the UK (or country of residence).	**D1** Evaluate how documentation is used to identify risks and hazards in the workplace.
LO2 Explain how system monitoring technology has been developed within engineering systems to improve quality and reliability of outputs		
P3 Explain a condition monitoring technique that could be used in a given engineering process. **P4** Calculate the failure rates for a range of components, using given data from an engineering process. **P5** Describe the factors affecting the reliability of a given engineering system.	**M2** Analyse the environmental conditions that could lead to the early failure of an engineering system and suggest methods to mitigate their effect.	**D2** Evaluate the criteria used to justify multiple test points in complex engineering systems requiring condition monitoring.

Pass	Merit	Distinction
LO3 Outline a range of monitoring and test equipment within an engineering environment		
P6 Outline suitable monitoring and test equipment for continual measurement of a given system parameter. **P7** Describe an investigation required when a condition monitor has recorded an increased temperature (or other parameter) within an engineering system.	**M3** Analyse the limitations of a typical condition monitoring equipment.	**D3** Evaluate the implications of a fault occurring in a condition monitoring circuit giving false readings.
LO4 Apply a range of fault diagnosis techniques to engineering systems.		
P8 Identify three different fault-finding techniques that could be used to diagnose a fault on an engineering system.	**M4** Demonstrate a logical approach to given fault-finding exercises.	**D4** Evaluate fault conditions within an engineering system and distinguish between symptoms, faults and causes.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird, J.O. and Ross, C.T.F. (2015) *Mechanical Engineering Principles*. 3rd ed. Abingdon: Routledge.

Hughes, P. and Ferrett, E. (2015) *Introduction to Health and Safety at Work*. 5th ed. Amsterdam: Elsevier.

Links

This unit links to the following related units:

Unit 4016: Instrumentation and Control Systems

Unit 4018: Maintenance Engineering

Unit 4084: Engineering Plant Operations and Maintenance.

Unit 4082: Introduction to Plant Commissioning and Decommissioning

Unit code J/617/3936

Unit level 4

Credit value 15

Introduction

The investment made by manufacturing operations in equipment and machinery (plant) is vast. The correct and efficient installation of new plant is vital to ensure operations start as soon as possible with the minimum of disruption to production. Likewise, when plant has reached the end of its useful life it must be removed and disposed of in a cost-effective and environmentally friendly way. These two processes are normally referred to as commissioning and decommissioning of plant.

The aim of this unit is to introduce the student to the planning necessary before beginning either process, the identification of any particular hazards that present special requirements beyond normal Health and Safety considerations, and the proper sequencing of work and use of specialist engineers or trades. Pre-production acceptance testing will also be covered, and issues of cost will be explored. End-of-life planning and procurement of replacement plant will be considered, as will the disposal by sale or scrapping of decommissioned plant. Proper recording of all processes will be emphasised.

On successful completion of this unit the student will be able to plan and carry out successful commissioning and decommissioning operations to the appropriate and agreed standards in an economical and environmentally friendly way.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Review the information and regulations applicable to the planning of commissioning and decommissioning of manufacturing plant

LO2 Apply a commissioning or decommissioning procedure in a manufacturing operation to ensure the most efficient, cost-effective and safe method of working

LO3 Describe the need for, and type of, acceptance and start-up tests necessary when commissioning manufacturing plant

LO4 Undertake the planning and commissioning/decommissioning of manufacturing plant.

Essential Content

LO1 **Review the information and regulations applicable to the planning of commissioning and decommissioning of manufacturing plant**

Information required:

Specifications and operational schedules for plant being commissioned/decommissioned

Equipment manufacturers' manuals, equipment-specific Health and Safety guidance, dimensions and mass of equipment being installed, company policies, production schedules, agreed timescales for process, required staff expertise, availability of staff and installation equipment required

Management of process.

Statutory regulations – the responsibility of employers and employees with regard to statutory regulations in the workplace, including:

Health and Safety at Work Act (HSWA)

Management of Health and Safety at Work Regulations (MHSWR)

Provision and Use of Work Equipment Regulations (PUWER)

Control of Substances Hazardous to Health (COSHH)

Lifting Operations and Lifting Equipment Regulations (LOLER)

Working at Height Regulations

Manual Handling Operations Regulations

Personal Protection Equipment at Work Regulations (PPE)

Confined Spaces Regulations

Electricity at Work Regulations

Control of Noise at Work Regulations

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

Construction Design and Management Regulations (CDM)

Health and Safety Executive's Approved Code of Practice (ACoP)

Health and Safety Executive guidance notes and safety signs.

Organisational safety requirements:

The responsibility of the employee for following company policies on Health and Safety

Adhering to required safety practices and routines.

Information sources:

Health and Safety Executive guidance

Manufacturers' manuals

The company's own policies and guidelines.

LO2 **Apply a commissioning or decommissioning procedure in a manufacturing operation to ensure the most efficient, cost-effective and safe method of working**

Plan procedure:

Determine operational objectives for commissioning or decommissioning

Identify Health and Safety requirements

Identify systems and services specific to site

Determine resource requirements (human and physical)

Agree timescales and schedule process; ensure that timescales and schedules minimise disruption and possibility of lost production

Identify costs

Prepare documentation

Conduct operator training prior to commissioning

Implement communication and feedback strategy with evaluation criteria.

LO3 **Describe the need for, and type of, acceptance and start-up tests necessary when commissioning manufacturing plant**

Need for acceptance tests:

Importance of correct operation on first operational use

Acceptance tests: component test; start-up and shut-down tests; full load, part-load and steady state running; tests of malfunction warnings and alarms

Consideration of failure procedures, operator error procedures, bedding down.

Recording and evaluation:

Collection of source data; records of performance characteristics; data analysis, evaluation and feedback; corrective action.

LO4 **Undertake the planning and commissioning/decommissioning of manufacturing plant.**

Planning:

Conduct commissioning/decommissioning planning and acceptance tests

Agree timescale, feedback and evaluation processes

Plan sale or disposal of decommissioned plant, e.g. scrap, re-engineering, use as development plant, environmental considerations and regulations

Observe equipment-specific Health and Safety requirements.

Commissioning/decommissioning:

Monitor adherence to plan

Take action on unavoidable deviation from plan

Conduct acceptance testing and receive feedback

Conduct sale or disposal of decommissioned plant

Complete handover documentation

Evaluate commissioning/decommissioning process on completion.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Review the information and regulations applicable to the planning of commissioning and decommissioning of manufacturing plant</td><td rowspan="4">LO1 and LO2
D1 Justify the operational objectives for a given commissioning or decommissioning requirement.</td></tr>
<tr><td>P1 Detail the information, and its sources, required to prepare a commissioning or decommissioning plan.
P2 Review the relevant statutory and organisational regulations for a given commissioning or decommissioning requirement.</td><td>M1 Illustrate how any commissioning or decommissioning requirement can be achieved with minimum disruption to manufacturing output.</td></tr>
<tr><td colspan="2">LO2 Apply a commissioning or decommissioning procedure in a manufacturing operation to ensure the most efficient, cost-effective and safe method of working</td></tr>
<tr><td>P3 Explain the need for detailed commissioning or decommissioning procedures prior to work starting.
P4 Assess the Health and Safety requirements for given commissioning or decommissioning procedures.</td><td>M2 Design a detailed process, including Health and Safety requirements, for a given commissioning or decommissioning procedure.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Describe the need for, and type of, acceptance and start-up tests necessary when commissioning manufacturing plant		**D2** Evaluate the way in which the results of acceptance and start-up testing can be analysed.
P5 Outline the purpose of post-commissioning acceptance and start-up testing. **P6** Describe the full range of acceptance and start-up testing of a new piece of plant after commissioning.	**M3** Discuss how operator errors associated with newly commissioned plant can be reduced or eliminated.	
LO4 Undertake the planning and commissioning/decommissioning of manufacturing plant.		**D3** Evaluate the effectiveness of given completed commissioning/ decommissioning plans.
P7 Produce a commissioning or decommissioning plan for a given piece of manufacturing plant equipment.	**M4** Analyse the alternative methods of disposing of decommissioned plant.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Mobley, K. (2014) *Maintenance Engineering Handbook*. 8th Ed. New York: McGraw Hill.

Richardson, D.C. (2013) *Plant Equipment and Maintenance Engineering Handbook*. New York: McGraw Hill.

Websites

http://www.soe.org.uk	Society of Operations Engineers Plant operations (General reference)

Links

This unit links to the following related units:

Unit 4081: Monitoring and Fault Diagnosis of Engineering Systems

Unit 4083: Creating and Managing Projects in Manufacturing Operations

Unit 4084: Engineering Plant Operations and Maintenance.

Unit 4083: Creating and Managing Projects in Manufacturing Operations

Unit code	**L/617/3937**
Unit level	**4**
Credit value	**15**

Introduction

Many people, working in widely differing industries, describe themselves as project managers. It means that their expertise is in bringing together all the people, materials and processes, in the right order, at the best possible time, required to achieve a clearly defined output for a project in the most effective and economical way.

In manufacturing operations, a project can be as complex as the design and build of a new motor car, or as simple as the task of installing a new piece of equipment.

This unit introduces the student to the elements that constitute a project, the tools available to help achieve the specified outcome and the role of the project team and the project manager in the process. They will examine the criteria for the success or failure of a project, evaluate project management systems, and consider the reflective and analytical processes involved in the appraisal of the finished project. Students will also examine the need for structured organisation and responsibility; effective control, coordination and reporting; and communication and leadership within the project team.

On successful completion of the unit, students will be able to define a project, create project plans, set up the delivery of the project, execute and review the outputs, and understand the outcomes – how the project fits into the wider business planning strategy of the organisation.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the role and process of delivering projects in manufacturing operations

LO2 Describe the principles of project management and the tools available to assist the process

LO3 Specify the elements of a project plan in terms of organisation and people

LO4 Create a project plan for a specified outcome.

Essential Content

LO1 **Explain the role and process of delivering projects in manufacturing operations**

Project management:

Project management and the role of the project manager

Management of change

Elements of project management systems and their integration.

Project environment and the impact of external influences:

Identification of the major project phases and their importance

Nature of the work in each phase.

Success/failure criteria:

Need to meet operational, time and cost criteria

Definition and measurement of success, project scope, product breakdown structure (PBS), work breakdown structure (WBS), project execution strategy

Role of the project team

Considerations of investment appraisal, discount cash flow (DCF) and net present value (NPV).

Project process analysis:

Benefit analysis and viability of projects

Determination of success/failure criteria, project termination

Preparation of project definition report

Acceptance tests

Report (monthly) on rejects/defects and failure analysis with respect to manufacturing problems; corrective actions, including material or processing changes, improved operator training, enhanced quality controls.

LO2 **Describe the principles of project management and the tools available to assist the process**

Organisational structure:

Functional, project and matrix organisational structures

Consideration of cultural and environmental influences

Organisational evolution during the project lifecycle

Job descriptions and key roles in the project team

Influence of the project sponsor or owner, champion, manager, integrators, users and stakeholders.

Roles and responsibilities:

Planning, scheduling and resourcing techniques

Preparation of project plans

Operator training/re-certification

Monitoring and control.

Control and coordination:

Use of work breakdown structures to develop monitoring and control systems

Performance monitoring and progress measurement against established targets and plans

Project reporting

Changes in control procedures, documentation version control

Importance of cascading, communications briefing, instilling trust and confidence in others.

Leadership requirements:

Stages of team development; Belbin's team roles; motivation and team building

Project leadership styles and attributes

Delegation of work and responsibility

Techniques for dealing with conflict; negotiation skills; chairing meetings.

Human resources and requirements:

Calculation, specification and optimisation of human resource requirements

Job descriptions

Formation of project teams

Project initiation and start-up procedures.

LO3 **Specify the elements of a project plan in terms of organisation and people**

Project management plans:

The 'why, what, how, when, where and by whom' of project management

Contract terms and document distribution schedules

Procurement

Establishing the baseline for the project.

Scheduling techniques:

Relationship between schedules

OBS and WBS; bar charts; milestone schedules; network techniques; resourcing techniques; computer-based scheduling and resourcing packages; project progress measurement and reporting techniques; staff-hours earned value and progress, 'S' curves; critical path analysis and reporting; milestone trending.

Cost control techniques:

Cost breakdown structure, resources needed

Types of project estimate, estimating techniques, estimating accuracy, contingency and estimation, bid estimates, whole-life cost estimates; computer-based estimating

Sources of information, sensitivity of cost information

Allocation of budgets to packages of work; committed costs; actual costs; cash flow; contingency management.

Performance:

Cost−performance analysis; budgeted cost for work scheduled (BCWS)

Budgeted cost for work performed (BCWP)

Concept of earned value

Actual cost of work performed (ACWP)

Cost−performance indicators.

Termination of the project:

Audit trails

Close-out reports.

Post-project appraisals:

Comparison of project output/outcome with business objectives

Process of self-reflection on project process and outputs/outcomes.

LO4 **Create a project plan for a specified outcome.**

Production of a project plan:

Agreeing timescales and expected outcomes

Drafting and correcting proposals

Seeking and using expert feedback

Selecting suitable project management tools

Producing final plan

Presentation of plan

Reflective analysis of the final project plan.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the role and process of delivering projects in manufacturing operations		
P1 Explain the principles of project management. **P2** Describe the role of success/failure criteria in project development. **P3** Detail the key elements in determining the viability of a project.	**M1** Analyse the key elements in determining the viability of a project.	**D1** Evaluate the viability of a given project with particular emphasis on success/failure criteria.
LO2 Describe the principles of project management and the tools available to assist the process		
P4 Identify the main elements of a project plan. **P5** Detail the role of scheduling techniques in a project plan. **P6** Describe the role of control and coordination in the delivery of a project plan.	**M2** Analyse the importance of leadership in the role of the project team.	**D2** Evaluate the techniques available to prevent conflict in a small project team.
LO3 Specify the elements of a project plan in terms of organisation and people		
P7 Specify the key elements of a project plan. **P8** Describe the most important cost control methods available to manage a project plan. **P9** Explain how project performance tools are used to manage a project.	**M3** Analyse the most appropriate project management organisation tools for a given project.	**D3** Evaluate the effectiveness of cost and performance control methods used in a given project.
LO4 Create a project plan for a specified outcome.		
P10 Design a project plan for a specified job within a familiar area of work.	**M4** Analyse the project management tools selected to assist with the delivery and monitoring of the project plan.	**D4** Evaluate the effectiveness of the project plan produced in the light of expert and peer group feedback.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Newton, R. (2016) *Project Management Step by Step*. 2nd ed.
Harlow:
Pearson Education.

Smith, N.J. (2007) *Engineering Project Management*. 3rd ed. Oxford: Wiley-Blackwell.

Websites

http://www.apm.org.uk	Association for Project Management (General reference)
http://www.cipmglobal.org	Charted Institute of Project Management (General reference)
https://institute.pm	Institute of Project Management (General reference)

Links

This unit links to the following related units:

Unit 4008: Managing a Professional Engineering Project

Unit 4078: Manufacturing Planning and Scheduling Principles.

Unit 4084: Engineering Plant Operations and Maintenance

Unit code	**D/617/3943**
Unit level	**4**
Credit value	**15**

Introduction

Modern manufacturing industries require complex and costly equipment which must be operated and maintained at maximum efficiency with the minimum amount of lost production due to breakdown or routine maintenance. Properly scheduled inspection and maintenance are vital to detect problems or prevent them before they occur.

This unit will examine ways in which inspection and maintenance can be scheduled and operated; the influence of statutory and organisational regulations; the importance of safe working; and appropriate maintenance techniques. The importance of data collection and analysis to ensure maximum system performance will also be investigated.

On successful completion of this unit the student will be able to explain the importance and operation of a range of maintenance schedules and techniques, as well as techniques for data collection and analysis to assess system performance.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Describe the importance of scheduled inspection and maintenance for the efficient operation of modern manufacturing operations

LO2 Demonstrate the importance of safe working and adherence to statutory and organisational regulations in minimising accidents and equipment down time

LO3 Assess the effectiveness of a range of inspection and maintenance schedules and techniques in given plant operations

LO4 Apply data collection and analysis techniques to assess system performance and maximise operational efficiency.

Essential Content

LO1 **Describe the importance of scheduled inspection and maintenance for the efficient operation of modern manufacturing operations**

Need for scheduled inspection and maintenance:

Definition of, and need for scheduled inspection and maintenance

Benefits: production efficiency, extended operating life, increased uptime, reduced downtime, increased mean time between failure.

Types of maintenance:

Planned, preventative, predictive, scheduled, unscheduled, corrective and emergency.

Scheduling and monitoring:

Importance of dead time scheduling, manual and automated recording systems, built-in maintenance notification, lock-out systems.

LO2 **Demonstrate the importance of safe working and adherence to statutory and organisational regulations in minimising accidents and equipment down time**

Working safely:

Rules for employee safety, use of safety devices and guards, lock out, tag out, electrical safety fall protection

Development and implementation of safe schemes of work

Permit to work, lone working and emergency procedures

Use of control measures (ERIC – SP)

Purpose of risk assessment and method statements for maintenance procedures.

Statutory regulations – responsibilities of employers and employees with regard to statutory regulations in the workplace, including:

Health and Safety at Work Act (HSWA)

Management of Health and Safety at Work Regulations (MHSWR)

Provision and Use of Work Equipment Regulations (PUWER)

Control of Substances Hazardous to Health (COSHH)

Lifting Operations and Lifting Equipment Regulations (LOLER)

Working at Height Regulations

Manual Handling Operations Regulations (MHOR)

Personal Protection Equipment at Work Regulations (PPE)

Confined Spaces Regulations

Electricity at Work Regulations

Control of Noise at Work Regulations

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

Construction Design and Management Regulations (CDM)

Health and Safety Executive's Approved Code of Practice (ACoP)

Health and Safety Executive guidance notes and safety signs.

Organisational safety requirements − the responsibility of the employer and employee with regard to organisational safety requirements, including:

Responsibility of the employee for the safety of self and others; safety groups, informal discussion or presentation that focus on various safety issues, e.g. Safety Share, Toolbox Talk, Tailgate, Tailgate Safety Meeting, Safety Moments

Company policies on Health and Safety, setting out practices/routines to ensure all relevant regulations are met and everyone operating or maintaining machinery is safe

Developing a safety culture

The role of the Health and Safety Executive (HSE) and the power of inspectors/right of inspection; improvement notices and prohibition notices.

LO3 **Assess the effectiveness of a range of inspection and maintenance schedules and techniques in given plant operations**

Maintenance strategies:

Determination of operational objectives

Predictive component failure, bathtub curve, equipment design life and requirements for periodic maintenance

Reactive, preventative, predictive and reliability-centered maintenance; comparison of presented maintenance programmes

Maintenance schedules, resource requirements and costs, documentation, maintenance procedures against prepared criteria.

Maintenance techniques:

Importance of isolation and making safe before undertaking maintenance

Adherence to Permit to Work process and shift changeover procedures

In-service (live) preventative maintenance, e.g. thermographic survey, partial discharge inspection

Compliance with manufacturers' recommended inspection and maintenance procedures, using manufacturers' data as case studies

'Look, listen and feel' approach

Visual inspections

Electrical and mechanical measurements; mechanical operations test

Functional tests, e.g. switching mechanisms.

LO4 **Apply data collection and analysis techniques to assess system performance and maximise operational efficiency.**

Data collection:

Types of data collection and recording

Relevance and reliability of data sources

Determination of data parameters

Methods of data collection

Automation of data collection

methods of data recording.

Data analysis:

Comparison of collected data with published/expected outputs of the system under scrutiny

Recognition of steady-state data and intervention points

Automated analysis and alarm systems

Comparison of recorded data with operational objectives

Remedial responses to analysed data – maintaining production capability.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the importance of scheduled inspection and maintenance for the efficient operation of modern manufacturing operations		
P1 Identify the reasons why scheduled inspection and maintenance are essential in manufacturing operations. **P2** Describe the types of maintenance associated with engineering operations.	**M1** Analyse ways in which maintenance can be completed without interrupting manufacturing operations.	**D1** Evaluate the consequences of poor maintenance to the efficiency of manufacturing operations.
LO2 Demonstrate the importance of safe working and adherence to statutory and organisational regulations in minimising accidents and equipment down time		
P3 Describe the key features of Health and Safety and safe working applicable to conducting effective maintenance. **P4** Demonstrate methods used to identify risks and their associated hazards.	**M2** Analyse the responsibilities of employees in maintaining a safe working environment.	**D2** Evaluate the effectiveness of the methods used to deal with identified hazards in given workplace situations.

Pass	Merit	Distinction
LO3 Assess the effectiveness of a range of inspection and maintenance schedules and techniques in given plant operations		**D3** Evaluate the maintenance requirements and techniques of a given manufacturing operation.
P5 Assess the range of maintenance strategies applicable to manufacturing operations. **P6** State the most applicable maintenance techniques for a given manufacturing operation.	**M3** Justify the importance of keeping accurate records of completed maintenance.	
LO4 Apply data collection and analysis techniques to assess system performance and maximise operational efficiency.		**D4** Evaluate data and analysis from a given set of information and suggest the most appropriate action to be taken to prevent equipment breakdown.
P7 Outline the most important data collection methods applicable to a manufacturing operation. **P8** Apply data collection and analysis techniques for a given manufacturing operation and present data.	**M4** Analyse given data to identify steady state operation and points of intervention.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Mobley, K. (2014) *Maintenance Engineering Handbook*. 8th Ed. New York: McGraw Hill.

Richardson, D.C. (2013) *Plant Equipment and Maintenance Engineering Handbook*. New York: McGraw Hill.

Websites

http://www.soe.org.uk	Society of Operations Engineers Plant Maintenance (General reference)
http://www.imeche.org	Institute of Mechanical Engineers (General reference)
http://www.hse.gov.uk	Health and Safety Executive (General reference)

Links

This unit links to the following related units:

Unit 4018: Maintenance Engineering

Unit 4081: Monitoring and Fault Diagnosis of Engineering Systems

Unit 4082: Introduction to Plant Commissioning and Decommissioning.

Unit 4085: Mechatronic Systems in Manufacturing

Unit code	**K/617/3945**
Unit level	**4**
Credit value	**15**

Introduction

Mechatronic systems are a fusion of different engineering disciplines including electrical, electronic and mechanical engineering, and control and computer systems engineering. This integration of technologies enables greater automation in manufacturing, leading to time saving, increased output and cost savings. Examples of mechatronic systems include integrated automated production lines; measuring, testing and calibration systems for quality control; and closed-loop control systems for process optimisation.

Topics within this unit include the evolution, design and characteristics of mechatronic systems; sensors, transducers and actuators; closed-loop feedback systems; programmable control devices; interfacing; system integration design; and functional safety requirements.

On successful completion of this unit students will be able to explain the design and operational characteristics of a mechatronic system, identify and apply a range of sensors, transducers and actuators, evaluate programmable control devices and design an integrated mechatronic system for a manufacturing specification.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the design and operational characteristics of a manufacturing mechatronic system

LO2 Investigate a range of mechatronic system components and technologies

LO3 Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system

LO4 Design a mechatronic system for a manufacturing application.

Essential Content

LO1 **Explain the design and operational characteristics of a manufacturing mechatronic system**

Origins, evolution and applications:

History and early development; evolution from purely mechanical to integrated mechatronic systems

Industrial robots and alternative applications, e.g. vehicle driver assistance systems, medical applications, domestic goods, space exploration, sports and leisure systems.

Elements of a mechatronic system:

Physical system modelling; sensors and actuators; control and feedback signals; data acquisition and processing; computerised control; overview of open and closed-loop control systems.

Mechatronic system integration:

Conventional systems versus mechatronic systems for manufacturing and inspection stages; high-performance versus lower cost; interpreting system requirements; understanding system constraints; selection and placement of sensors; interface matching; reliability and safety.

LO2 **Investigate a range of mechatronic system components and technologies**

Analogue and digital signals:

Continuous versus discrete signals; voltage (0-10 v) versus current (4-20 mA)

Amplification and attenuation, sources of noise, filtering, Analog-to-Digital Converter (ADC) resolution, pulse width modulation.

Sensors and transducers:

Temperature, light level, force, pressure, speed, position, proximity, sound, flow, humidity, vibration, voltage, current

Interpreting data sheets; selection criteria; calibration and testing.

Actuators:

Types: linear, rotary, hydraulic, chain, pneumatics

Applications: valves, motors, servomechanism (servo), micro-positioning motors

Interpreting data sheets; selection criteria; mounting, force, torque, enclosure protection

National Electrical Manufacturers Association (NEMA) and International Electrotechnical Commission (IEC).

LO3 **Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system**

Microcomputer system architecture:

CPU, memory, data, program, input/output (I/O), data and address bus.

Programmable logic controllers (PLCs):

Selection criteria: size, functionality, flexibility, performance, connectivity, security, manufacturers

Programming: IEC 61131-3 Languages, software tools

Advantages and disadvantages of PLCs

Interfacing to a mechatronic system.

Microcontrollers:

Selection criteria: processor, speed, memory, power, range of I/O

Programming languages: C, C++, assembly and alternative third-party and open-source software

Software tools: debuggers, emulators, simulators

Advantages and disadvantages of microcontrollers

Interfacing to a mechatronic system.

Alternative programmable control devices:

Programmable automation controller (PAC), industrial PC based robot controllers, remote telemetry units (RTU), field programmable gate array (FPGA).

Functional Safety:

International Engineering Consortium (IEC) standard IEC61508

Hazard and risk assessment (HARA)

Safety integrity levels (SILs) of programmable devices.

LO4 **Design a mechatronic system for a manufacturing application.**

Design methodologies:

Identification of skill sets required by team members for a mechatronic system project

Interpreting requirements to develop concept design and specification

VDI 2206 (guideline for the design of mechatronic systems): general cycle of problem solving on the micro level; the V-shaped model on the macro level

Process modules for repeating design steps; advanced design modelling and simulating system behaviour.

Functional Safety:

International safety standards: ISO 13849-1, IEC 61061,2006/42/EC, IEC 618005-2

European Machinery Directive 2006/42/EC for safety-related parts of a control system (SRP/CS), integrating safety into the design process

Hazard and risk assessment: hazard and operability study (HAZOP), failure modes and effects analysis (FMEA), fault tree analysis (FTA)

Use of multi-function safety relays.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the design and operational characteristics of a manufacturing mechatronic system		
P1 Describe the key elements of a mechatronic system. **P2** Explain the origins, evolution and benefits of mechatronic systems in manufacturing.	**M1** Analyse how system integration has transformed conventional manufacturing mechatronic systems.	**D1** Evaluate the operation of a mechatronic system within a manufacturing environment characterizing the different technologies and interfaces.
LO2 Investigate a range of mechatronic system components and technologies		
P3 Identify the types of sensors and transducers used within a manufacturing mechatronic system. **P4** Identify the types of actuators used within a manufacturing mechatronic system.	**M2** Justify a range of instrumentation devices for a given mechatronic system design specification.	**D2** Evaluate types of signals used in instrumentation devices and a range of signal processing techniques used when integrating mechatronic systems.

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system</td><td rowspan="2">D3 Evaluate a programmable control device for a given mechatronic system application with consideration to Functional Safety.</td></tr>
<tr><td>P5 Describe the characteristics of programmable logic controllers and applications within manufacturing mechatronic systems.

P6 Describe the characteristics of embedded microcontrollers and applications within manufacturing mechatronic systems.</td><td>M3 Analyse the operation and interfacing of a range of programmable control devices used in manufacturing mechatronic systems.

M4 Analyse the range of programming languages and software tools available for programmable control devices used within manufacturing mechatronic systems.</td></tr>
<tr><td colspan="2">LO4 Design a mechatronic system for a manufacturing application.</td><td rowspan="2">D4 Justify the selection of components and technologies for the development of a manufacturing mechatronic system.</td></tr>
<tr><td>P7 Interpret a set of requirements to a specification for a manufacturing mechatronic system.

P8 Produce a block diagram to illustrate the design of a manufacturing mechatronic system, documenting appropriate design methodology.

P9 Design a mechatronic system based on a given specification and block diagram.</td><td>M5 Assess compliance, safety and risk management issues present in the design solution.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Alciatore D. (2018) *Introduction to Mechatronics and Measurement Systems*. 5th Ed. McGraw Hill.

Bolton, W. (2015) *Mechatronics.* 6th Ed: *Electronic Control Systems in Mechanical and Electrical Engineering*. Harlow: Pearson Education.

Clarence, W. de S. (2010) *Mechatronics: A Foundation Course*. Boca Raton, Florida: CRC Press.

Tacchini M. (2023) *Functional Safety of Machinery: How to Apply ISO 13849-1 and IEC 62061*. Wiley.

Websites

http://www.inderscience.com	Inderscience Publishers International Journal of Mechatronics and Manufacturing Systems International Journal of Automation and Control International Journal of Mechatronics and Automation
http://www.controleng.com	Control Engineering Integrating safety into engineering into mechatronic design Top-down strategies for innovation in mechatronic machine engineering When to use multi-function safety relays (General reference)
http://www.howtomechatronics.com	How to Mechatronics 'How it works' (Briefings)

http://www.vdi.eu	Association of German Engineers VDI-Standard VDI 2206: Design Methodology for Mechatronic Systems (General reference)

Links

This unit links to the following related units:

Unit 4033: Programmable Logic Controllers (PLCs)

Unit 4068: Industrial Robots

Unit 4080: Material Handling Systems.

Unit 4086: Introduction to Manufacturing Systems Engineering

Unit code D/651/0808

Unit level 4

Credit value 15

Introduction

Manufacturing systems engineering is concerned with the design and on-going operation and enhancement of the elements within a manufacturing system. While this unit refers to the underlying principles of Manufacturing Systems Engineering, the sectors of particular focus are automotive, food and drink, and textile manufacture.

This unit introduces the student to the complexity of a modern manufacturing environment. The topics cover all elements that make up a manufacturing system, including: production engineering, plant and maintenance engineering, product design, logistics, production planning and control, forecast Quality Assurance, accounting and purchasing, all of which work together within the manufacturing system to create the final output.

On successful completion of this unit students will be able to describe the main elements of a modern manufacturing system and explain how existing systems can be improved through the use of measuring and acquiring data and using it to optimize the process. They will also be confident to review systems of production planning and control.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the principles of manufacturing systems engineering and their relevance to the design and development of manufacturing systems

LO2 Demonstrate how a range of analysis tools, including value stream mapping, can be used to determine the effectiveness and efficiency of a manufacturing system

LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system

LO4 Assess the impact of manufacturing systems engineering on a manufacturing operation.

Essential Content

LO1 **Explain the principles of manufacturing systems engineering and their relevance to the design and development of manufacturing systems**

Underpinning principles of manufacturing systems engineering:

Making the production process as efficient as possible

Importance of continuous analysis, research and development of the process.

Manufacturing systems control elements:

Quality, cost, delivery performance and optimisation of output.

Development and management of manufacturing systems:

Problem solving, maintenance scheduling and planning, resource planning and productivity

Effect of testing and data analysis on system performance.

LO2 **Demonstrate how a range of analysis tools, including value stream mapping, can be used to determine the effectiveness and efficiency of a manufacturing system**

Analysis tools:

Introduction to value stream mapping; the value of both current state mapping and future state mapping

Bottle-neck analysis, using process improvement tools and techniques (value stream analysis, simulation, Kanban).

Using key performance indicators (KPIs) to understand the performance of a manufacturing system:

Overall equipment effectiveness, lead time, cycle time, waiting time, yield, delivery performance, safety metrics

Reviewing key performance indicators

Methods for presenting metrics and performance (balanced scorecards, performance dashboards, Andon boards, Gemba walks).

LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system

Production planning approaches:

Examples of production planning strategy: push versus pull factors, Kanban systems, make to stock, make to order and engineer to order, just-in-time (JIT) production, modular design, configuration at the final point, and master scheduling.

Production planning management tools:

Enterprise resource planning (ERP) systems, material resource planning (MRP 2) and manufacturing execution systems; ability to manage complexity and resourcing through information technology.

Industrial engineering issues:

The importance of standard time manufacturing and the impact on productivity and the costing of products

How standard work underpins the repeatability of process and quality control.

LO4 Assess the impact of manufacturing systems engineering on a manufacturing operation.

Effectiveness of manufacturing systems:

Plant layout design, cleanliness of manufacturing and test areas, planning, work instructions and control, productivity and continuous improvement, quality control in process inspection and test, final inspection and test, equipment effectiveness.

Manufacturing information technology:

Supply of data from the process to decision makers, e.g.: failure modes for both product and system, maintenance and down-time data, standard time for production, material control, energy usage

Importance of various data sources and identification of key elements for successful manufacturing operation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the principles of manufacturing systems engineering and their relevance to the design and development of manufacturing systems		
P1 Describe the underpinning principles of manufacturing systems engineering. **P2** Explain the role of the main control elements within manufacturing systems.	**M1** Identify the main features of a development process in manufacturing systems engineering.	**D1** Evaluate the impact that manufacturing systems have on the success of a manufacturing organisation.
LO2 Demonstrate how a range of analysis tools, including value stream mapping, can be used to determine the effectiveness and efficiency of a manufacturing system		
P3 Define the main features and applications of value stream mapping. **P4** Illustrate where current and future state mapping would be usefully employed within manufacturing systems.	**M2** Show how equipment efficiency may be measured in a typical manufacturing application.	**D2** Evaluate the effectiveness of the methods available to present key performance indicators (KPI) for a given manufacturing operations application.

Pass	Merit	Distinction
LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system		
P5 Outline the most important methods used to aid the development of production planning strategy. **P6** State how standard time manufacturing impacts on productivity and the costing process.	**M3** Analyse the effectiveness of production planning methods for a given process.	**D3** Evaluate a given production process and justify the most suitable production planning technique to improve productivity.
LO4 Assess the impact of manufacturing systems engineering on a manufacturing operation.		
P7 Outline the principal features that contribute to the effective operation of a manufacturing process. **P8** Explain how quality control and equipment effectiveness can influence the effectiveness of a manufacturing operation.	**M4** Analyse the critical data required by management to ensure the most efficient operation of a manufacturing process.	**D4** Evaluate the elements of a given manufacturing operation that contribute to its success, and suggest how it might be improved.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Baudin M. and Netland T. (2023) *Introduction to Manufacturing: An Industrial Engineering and Management Perspective.* Taylor & Francis.

Bicheno, J. and Holweg, M. (2009) *The Lean Toolbox*. 4th Ed. Buckingham: PICSIE Books.

Chopra, S. and Meindl, P. (2015) *Supply Chain Management: Strategy, Planning, and Operation.* 6th Ed. Harlow: Pearson.

Groover P. M. (2019) *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*. 7th Ed. Wiley.

Kalpakjian S. and Schmid S. (2022) *Manufacturing Engineering and Technology*. 8th Ed. Pearson.

Slack, N. (2013) *Operations Management*. 7th Ed. Harlow: Pearson.

Womack, J., Jones, D. and Roos, D. (1990) *The Machine that Changed the World*. New York: Free Press.

Websites

http://www.industryweek.com	Industry Week Five Benefits of MES (Article)

Links

This unit links to the following related units:

Unit 4017: Quality and Process Improvement

Unit 4074: Workplace Study and Ergonomics

Unit 4075: Business Improvement Techniques for Engineers

Unit 4077: Lean Techniques for Manufacturing Operations

Unit 4078: Manufacturing Planning and Scheduling Principles

Unit 4083: Creating and Managing Projects in Manufacturing Operations.

Unit 4087: Space Environment and Applications

Unit Code: H/650/3367

Level: 4

Credits: 15

Introduction

The Space Age began in 1957 with the launch of Sputnik – a small spacecraft which orbited the Earth for 92 days, transmitting simple radio signals to the ground and making measurements of the Earth's atmosphere. Today there are thousands of satellites in space, performing many different and complex roles, including broadcasting TV, monitoring climate and the environment, providing navigation services, taking detailed images of the Earth, and exploring space. Almost every aspect of modern life makes use of data and services provided by spacecraft and the sensors and instruments which they carry. The design, manufacture and operation of spacecraft is a vitally important and highly sophisticated industry, and technicians and engineers are at its heart.

The aim of this unit is to introduce students to the challenging environment of space, the different types of spacecraft, the kinds of missions which they perform, and the function of the main components which comprise a spacecraft. Among the topics taught in this unit are: case studies of applications of satellites and spacecraft; satellite structure; orbits; systems for power generation and storage; guidance, navigation and control; communications; data processing; payloads and instruments; propulsion; thermal control.

On successful completion of this unit, students will be able to describe the main components and systems which make up a typical satellite, and the way in which they interact to produce a fully functional spacecraft. They will be able to perform calculations to estimate the performance needed for different subsystems in response to mission requirements, and to identify appropriate solutions for specific kinds of missions, along with their limitations.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Explore the different segments, customer profiles, and occupations in the space sector

LO2 Examine the conditions associated with the space environment and how these impact on the space manufacturing industry

LO3 Discuss common applications for spacecraft and the general characteristics of the satellites and orbits used in each case

LO4 Investigate space systems and subsystems.

Essential Content

LO1 **Explore the different segments, customer profiles, and occupations in the space sector**

Overview of space sector and occupations:

The history and trends in space missions, satellite communications, and systems, through case studies

Segments in the space sector (including upstream and downstream)

Space sector applications, impacts on other sectors (e.g. agritech, transport, health) and related inventions and technological advances

Types of launch (including horizontal, vertical and future trends) and launch sites around the world

Space Engineering Technician (SET) as occupation; role of space technicians and progression opportunities; other equivalent occupations.

Customer demands:

Typical customer profiles (e.g. space agencies and satellite operators)

Typical customer projects, including upstream-focused and/or downstream-focused projects

Professional, statutory and regulatory bodies (PSRBs)

Relationships between customers, partners and suppliers in the international space engineering and manufacturing sector.

LO2 **Examine the conditions associated with the space environment and how these impact on the space manufacturing industry**

Overview of the space environment and conditions:

Discovery of the space environment

The space environment, including thermal, vacuum, radiation, atomic oxygen, and launch operations (e.g. crewed and uncrewed)

Orbital environments (e.g. thermal, atmosphere, radiation, disturbances)

Space weather and space weather predictions (e.g. solar flares, energetic particle events, coronal mass ejections)

Space debris, de-orbit guidelines, and the challenges of operating in a congested environment.

Impact of the space environment:

Effects of the space environment on materials, spacecraft systems, robotic systems and astronauts

Effects of the space environment on design, material selection, and testing

Overview of the types of tools used to model the effect of the space environment and improve performance

Overview of methods to mitigate spacecraft failures and associated impacts.

LO3 **Discuss common applications for spacecraft and the general characteristics of the satellites and orbits used in each case**

Common applications:

Definitions of a natural satellite and a spacecraft

Typical spacecraft characteristics (e.g. size) and mission types (including communications, broadcasting, weather, Earth observation, surveillance/defence, scientific research, planetary exploration, servicing, and position, navigation and timing (PNT) including reference frames).

Orbits:

Kepler's laws and basic orbits (elliptic, parabolic and hyperbolic)

Orbits including typical ranges of altitude, inclination and eccentricity, ground tracks, and specific types including geostationary, Molniya, sun-synchronous and Hohmann transfer

Scientific and exploration orbits and missions including Lagrange points

The process of entering and leaving orbits.

Mission and satellite characteristics:

Pointing and attitude control requirements, propulsion

Power requirements and typical duty cycles

Payload types (e.g. cameras, telescopes, clocks, radars, transmitters, repeaters and communications transponders).

LO4 **Investigate space systems and subsystems.**

Spacecraft as a system:

Spacecraft layout

System interfaces

Redundancy

Control loops and commanding

Concept of operations

Duty cycles.

Spacecraft subsystems:

Fundamental subsystems (including structure, communications, propulsion, attitude control, thermal control and stress analysis, power, onboard processing, data handling)

Common payload subsystems (including telescopes and imaging technology, timing and navigation, radar, communications services)

Deployable structures.

Requirements and design specification:

Customer requirements and technical budgets

Scientific and engineering principles and application of concepts to estimate subsystem performance parameters (e.g. communications-link budgets, solar-array sizing)

Trade studies for design selection

Preliminary design reviews and design specifications

Stakeholder engagement and decision-making.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore the different segments, customer profiles, and occupations in the space sector		**LO1 and LO2**
P1 Discuss the difference between the upstream and the downstream space sector segments and the typical roles within each. **P2** Explore the types of customers you would expect to commission a spacecraft manufacturing project linked to upstream and downstream, and how you might interact with them.	**M1** Analyse the current impact of the space sector and its segments on modern life and suggest ways that the space sector will impact on other sectors in the future.	**D1** Evaluate the effect of the space environment on a chosen system or subsystem, the impact on various manufacturing aspects, and suggest possible changes to improve performance.
LO2 Examine the conditions associated with the space environment and how these impact on the space manufacturing industry		
P3 Examine the conditions of space that make it a challenging environment for manufacturing a chosen space system, and the associated resources and processes. **P4** Explain what testing processes could be used to determine the effect of the space environment.	**M2** Analyse the environmental conditions that could lead to the early failure of a chosen system for space and suggest methods to mitigate the effect.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Discuss common applications for spacecraft and the general characteristics of the satellites and orbits used in each case</td><td rowspan="4">LO3 and LO4

D2 Prepare a quantitative preliminary design specification for a spacecraft, consisting of the core subsystems, to meet customer requirements for a given application.</td></tr>
<tr><td>P5 Investigate the range of applications and services that are served by satellites.

P6 Discuss the major characteristics of spacecraft and orbit design in order to serve specific applications.</td><td>M3 Summarise the primary requirements that drive the design and operational characteristics of space missions serving different applications.</td></tr>
<tr><td colspan="2">LO4 Investigate space systems and subsystems.</td></tr>
<tr><td>P7 Investigate the role of each of the core subsystems in the architecture of a space mission, and their relationship to other subsystems.

P8 Identify the key scientific and engineering principles underpinning the function of major spacecraft subsystems.</td><td>M4 Apply scientific and engineering principles to estimate performance parameters for a range of subsystems to support design decision-making.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Aguirre, M.A. (2013) *Introduction to Space Systems: Design and Synthesis*. Springer.

Fortescue, A., Swinerd, G. and Stark, J. (2011) *Spacecraft Systems Engineering.* 4th Ed. Wiley.

Kinckenor, M.M. and de Groh, K.K. (2020) *A Researcher's Guide to: Space Environmental Effects*. Rev. Ed. National Aeronautics and Space Administration.

NASA. (2017) *NASA Systems Engineering Handbook*. Rev. Ed. National Aeronautics and Space Administration.

Pisacane, V.L. (2016) *The Space Environment and its Effects on Space Systems*. 2nd Ed. American Institute of Aeronautics and Astronautics.

Rogers, L. (2008) *It's ONLY Rocket Science: An Introduction in Plain English*. Springer.

Websites

http://www.engineeringtoolbox.com	The Engineering ToolBox (General reference)
solarsystem.nasa.gov	NASA Science: Solar System Exploration 'Basics of Space Flight' (Tutorial)
http://www.esa.int	The European Space Agency (General reference)
http://www.kerbalspaceprogram.com	Kerbal Space Program (Development tool)
http://www.youtube.com/user/thenssi	The National Security Space Institute (NSSI) 'Space Environment' (General reference)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Thirsk, R., Kuipers, A., Mukai, C., et al. (2009) *The space-flight environment: the International Space Station and beyond*. *CMAJ*, 180(12), 1216–1220.

International Journal of Satellite Communications and Networking. ISSN: 1542-0981 (online).

IEEE Transactions on Communications. ISSN: 1558-0857 (online).

IEEE Communications Society monthly magazines.

Links

This unit links to the following related units:

Unit 4088: Space Technologies and Manufacturing

Unit 5052: Space Communications

Unit 5053: Space Mission Design.

Unit 4088: Space Technologies and Manufacturing

Unit Code: J/650/3368

Level: 4

Credits: 15

Introduction

The global space industry is growing steadily and many nations are building industrial strategies with a significant focus on the design and manufacture of spacecraft, ground segments, and novel materials for the space environment. With this growth, there will be a demand for specialist skills in space manufacturing, and a need for people to take up jobs such as space technicians, space technologists, space engineers, scientists and more.

The aim of this unit is to introduce students to the rigorous manufacturing, design, and testing required in space manufacturing in order to produce viable components. On successful completion of this unit, students will be able to understand the processes of assembly, integration and testing of the main components and systems which make up a typical spacecraft, through the use of numerical models, simulations and case studies. Students will be equipped with the knowledge to understand and use technical documentation and relevant quality management systems in order to apply strict quality assurance processes.

Students will be able to apply scientific and engineering knowledge to implement design decisions in response to project requirements, and to identify appropriate solutions for specific problems that may occur. Students will have developed key knowledge of smart materials used in space and the space manufacturing sector. They will develop a broad understanding of the environmental and sustainability drivers in the space industry, and be able to communicate this in technical reports and presentations.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Discuss the composition, physical properties and processing requirements of materials used in space manufacturing

LO2 Examine ground and space systems equipment using mechanical, electrical and electronic instruments

LO3 Assess processes and procedures to support quality and efficiency in space system manufacture and testing

LO4 Investigate the analytical and programmatic tools and processes used in the design and manufacture of spacecraft.

Essential Content

LO1 **Discuss the composition, physical properties and processing requirements of materials used in space manufacturing**

Materials suitable for use in space engineering:

Sources of materials in the supply chain

Properties of materials for use in space components

Handling and application of space-qualified materials

The effects of manufacturing and testing processes on materials' properties (including thermal vacuum, electromagnetic compatibility, shock, vibration and acoustic testing)

The use of 3D printing and additive manufacturing in space including powder quality and repeatability of build

The use of sustainable materials in space manufacturing.

Fabrication and assembly:

Appropriate joining, adhesives, bonding, plating, soldering and fastening techniques for space components

Ancillary materials and processes

Fabrication, assembly, integration and testing of equipment and products at system and subsystem level, such as electronics boards and mechanical assemblies, in facilities such as clean rooms and workshops.

LO2 **Examine ground and space systems equipment using mechanical, electrical and electronic instruments**

Testing principles:

Precision and uncertainty in measurement systems, including limitations and appropriate use; tolerancing and torque settings

Test standards and procedures in the space industry.

Mechanical and thermal testing:

Mechanical testing, fault-finding principles and techniques (using instruments such as pressure gauges, micrometers and balances, and non-contact approaches)

Thermal vacuum, electromagnetic compatibility, shock, vibration and acoustic testing

Vacuum and pressurised systems and measurement using documentation such as Piping and instrumentation diagrams (P&IDs).

Electrical and electronic testing:

Properties, handling and application of space-qualified materials including electrostatic discharge (ESD) precautions

Electrical and electronic measurement, testing and fault-finding (using equipment such as voltmeters, spectrum analysers and oscilloscopes).

Use and maintenance:

Use and maintenance of electrical/electronic test equipment and mechanical handling equipment for ground support equipment and systems

Use and maintenance of vacuum and pressure systems (such as environmental test chambers, pressure-fed propulsion systems, and gas supply lines for manufacturing and testing)

Use and maintenance of cryogenic systems for space applications (such as propulsion, subsystem thermal control and ground support activities)

Use, support and maintenance of ground support systems for spacecraft and subsystems.

LO3 **Assess processes and procedures to support quality and efficiency in space system manufacture and testing**

Processes and procedures:

Approved processes, components, parts and materials lists

Verification control documentation

Configuration and document management control processes (including issue control, incorporation of change, end-item data packages (EIDPs), and data handling)

Build and change records

Product lifecycle in space manufacturing.

Space standards:

Quality management systems including non-conformance reports, production documentation and published standards including EN9100 and ISO9001

Use of specialist space environments including clean rooms, workshops, test facilities and appropriate standards (e.g. ECSS-Q-ST-70-50C)

Environmental control (including cleanliness, particle contamination monitoring, temperature and humidity)

Health, safety and environment (HSE) requirements and working practices as they apply to the space manufacturing working environment, including pressurised systems, the use of personal protective equipment (PPE), and risk assessments

Space industry standards and product lifecycles.

Quality control:

Principles and levels of quality assurance (QA) and operational consideration (including QA responsibilities associated with inspection activities)

Internal and external quality management systems adopted in the space industry

Inspect electrical, mechanical or electronic equipment for QA purposes.

Documentation:

Complete documentation such as work instructions, technical build, and change records at the appropriate stages of the work activity

Standard operating procedures (SOPs), accurate record-keeping and monitoring, and the potential implications for safety, quality and delivery

Apply documentation control processes and procedures e.g. format, location access, authorisation

Technical reviews in space manufacturing programmes.

LO4 **Investigate the analytical and programmatic tools and processes used in the design and manufacture of spacecraft.**

Management, product assurance and quality assurance:

Project management tools (e.g. Microsoft Project, Gantt charts)

Approved processes, components, parts and materials lists, and verification control documentation

Work instructions, build and change records, risk assessments, and non-conformance reports in compliance with applicable space industry processes

Technical reviews such as assembly, integration and test readiness

Space 4.0, including low-cost access to space and privatisation of the space sector.

Analysis and design:

Create and interpret 3D models, simulation (e.g. computer-aided design (CAD)/computer-aided manufacture (CAM), product data management/product lifecycle management (PDM/PLM), thermal models and finite element analysis) and part drawings to enable analysis and manufacture of components for spacecraft systems and ground support equipment

Use of design specifications in the space industry

Problem-solving using procedures and methodologies commonly applied in the space engineering sector, such as failure modes and effects analysis (FMEA), the plan–do–check–act (PDCA) cycle, 8-disciplines (8D) problem-solving, Ishikawa (fishbone) diagrams

Read, extract and interpret technical documentation (such as workplans/project plans, schedules, drawings, test plans, specifications, production data, quality reports, costing data, statistical information, assembly instructions and requirements).

Improvement and customer delivery:

Approved processes and procedures to identify improvements to quality and efficiency, including the generation of engineering change requests

Manage internal and/or supplier quality notifications, and liaison with the stakeholders necessary for resolution

Contribute to the definition of space engineering process improvement plans.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Discuss the composition, physical properties and processing requirements of materials used in space manufacturing</td><td rowspan="5">LO1 and LO2

D1 Evaluate the types of materials and manufacturing processes commonly used in a space system component, how they can be tested, and suggest possible improvements through the use of suitable materials, 3D printing and additive manufacturing.</td></tr>
<tr><td>P1 Discuss the physical properties and supply chain for materials commonly used in the manufacture of spacecraft.

P2 Outline the joining and finishing processes required for a range of different materials in a space system design and show how they can be considered suitable for a space environment.</td><td>M1 Analyse the handling, joining, finishing and other ancillary processes for a range of different materials in a space system design to show how they can be considered suitable for a space environment.</td></tr>
<tr><td colspan="2">LO2 Examine ground and space systems equipment using mechanical, electrical and electronic instruments</td></tr>
<tr><td>P3 Examine the key equipment used in the mechanical, electrical and electronic testing of a space component.

P4 Evaluate a suitable mechanical, electrical and electronic testing process for a space component.</td><td>M2 Analyse three different fault-finding techniques that could be used to diagnose a fault within a space component.</td></tr>
</table>

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Assess processes and procedures to support quality and efficiency in space system manufacture and testing</td><td rowspan="5">LO3 and LO4

D2 Design a space manufacturing process which aligns with key space standards and identify improvements to quality and efficiency to meet customer needs.</td></tr>
<tr><td>P5 Discuss the role of published standards in space engineering.

P6 Assess workplace hazards and prescribed working practices for specialist space environments such as clean rooms.</td><td>M3 Analyse how standards adopted in the space sector influence the product lifecycle.</td></tr>
<tr><td colspan="2">LO4 Investigate the analytical and programmatic tools and processes used in the design and manufacture of spacecraft.</td></tr>
<tr><td>P7 Investigate the key elements in determining the technical compliance of a space manufacturing process, using tools where relevant.

P8 Design a project plan which complies with applicable space industry processes.</td><td>M4 Analyse how space project management tools and problem-solving methodologies can be used to identify improvements to a space manufacturing process.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Fortescue A., Swinerd G. and Stark J. (2011) *Spacecraft Systems Engineering.* 4th Ed. Wiley.

Kalpakjian S. and Schmidt S.R. (2021) *Manufacturing Engineering and Technology*. 7th Ed. Pearson Education.

Paton B. (2019) *Space Technologies, Materials and Structures*. Taylor & Francis.

Wertz W.J. and Larson W.J. (Editors) (1999) *Space Mission Analysis and Design*. 3rd Ed. Springer.

Qingjun Z. and Jie L. (Editors) (2023) *Spacecraft System Design − Space Science, Technology and Application Series (Hardback).* Taylor & Francis Ltd.

Sweeting M., Underwood C., Fortescue P. and Stark J. (Editors) (2023) *Spacecraft Systems Engineering (Hardback).* John Wiley & Sons Inc.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Acta Astronautica

Aerospace

Aerospace Science and Technology

Frontiers in Space Technologies

Journal of Space Safety Engineering

Journal of Spacecrafts and Rockets

Journal of Aerospace Engineering

Journal of Aircraft and Spacecraft Technology

Journal of Manufacturing Systems

Journal of Space Technology

Space: Science & Technology

SpaceQuip Journal

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4087: Space Environments and Applications

Unit 5052: Space Communications

Unit 5053: Space Mission Design.

Unit 4089: Net Zero Energy Technologies I: Systems and Demand

Unit Code: K/650/3369

Level: 4

Credits: 15

Introduction

Deep and drastic cuts in greenhouse gas emissions are needed to avoid irreversible climate breakdown. As of the Glasgow Climate Pact of November 2021, 80% of the global economy and 77% of global emissions are covered under 'net zero' targets.[1] Net zero targets are intended to reduce the amount of greenhouse gases emitted into the atmosphere such that they are no greater than those that are absorbed. The energy system is the largest contributing sector to greenhouse gas emissions.

The aim of this unit is to introduce students to the fundamentals of energy systems, net zero targets, and the technologies available to decarbonise energy demand across heating and cooling, transport, and electricity consumption.

On successful completion of this unit, students will understand the fundamentals of energy systems, including system infrastructure and demand. Students will also develop their understanding of net zero energy technologies and how these interact with energy demand and social practice. Finally, they will be able to investigate the suitability of different energy technologies for a given context.

[1] University of Oxford. (2021, November 1). 80% of world economy now aiming for net zero − but not all pledges are equal. https://www.ox.ac.uk/news/2021-11-01-80-world-economy-now-aiming-net-zero-not-all-pledges-are-equal

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Discuss the fundamentals of energy systems, demarcating supply, demand, and energy system infrastructure

LO2 Explain how key net zero energy technologies work across key sectors of energy demand

LO3 Examine how net zero energy technologies interact with energy demand and social practice

LO4 Analyse the suitability of different energy technologies in decarbonising energy demand in given geographical and socio-economic contexts.

Essential Content

LO1 **Discuss the fundamentals of energy systems, demarcating supply, demand, and energy system infrastructure**

Fundamentals of energy:

Heat and work

Conservation of energy

Conversion efficiencies

Why do we need energy? A breakdown of energy services for heating (including space heating, water heating, cooking, industrial processes), cooling, transport, lighting, machines, and appliances across sectors (residential, industrial, business, etc.).

Energy supply − sources and carriers:

Thermal fuels: brief introduction featuring both fossil fuels (coal, oil, fossil gas) and low-carbon thermal fuels (bioenergy, nuclear power), including costs, installation scale and historical trends

Renewable sources: brief introduction – wind energy, ocean and tidal energy, bioenergy, geothermal energy, hydropower, solar photovoltaic and solar thermal energy

Energy carriers: brief introduction – electricity, heat-exchanging fluids, producible fuels, e.g. hydrogen (including brief description of low-carbon 'green' hydrogen vs. fossil-fuel-derived 'blue' and 'grey' (with and without carbon capture) hydrogen), ammonia and synthetic hydrocarbons

Sankey diagrams as pictorial representations of energy supply.

Energy demand:

Heating and cooling, including space heating, water heating, cooking, industrial processes

Transport, including passenger and freight transport – surface, air and water

Electricity – lighting, machines and appliances – including residential and industrial uses.

Energy system infrastructure:

Electricity systems: generation, transmission and distribution

Gas systems: sources, transmission and distribution

Fuel supply chains

Low-carbon electricity systems (distributed generation, smart grids)

Net zero energy systems (whole-system interactions) and Industry 4.0 – readiness, relevance and priorities.

LO2 **Explain how key net zero energy technologies work across key sectors of energy demand**

Heating and cooling:

Residential heating and cooling demand: historical and projected

Industrial and commercial heating and cooling demand: historical and projected

Demand reduction and demand management (thermal insulation of dwellings, behavioural change in heating and cooling)

Heat pumps/air conditioners

District heating/cooling

Hydrogen for heating

Solar thermal

Bioenergy and waste heat.

Electricity for lighting, machines and appliances:

Residential electricity demand: historical and projected

Industrial and commercial electricity demand: historical and projected

Electrification of energy demand: scenarios for growth in electricity demand.

Transport:

Passenger transport demand: historical and projected

Freight transport demand: historical and projected

Demand reduction and demand management (modal shift from private cars to public transport and active travel, limiting aviation demand)

Electric road vehicles (EVs) – battery electric, hydrogen fuel cell and hybrid vehicles for passenger and freight road transport

Low-emission rail – electric (overhead/electrified rail), hydrogen and battery-electric

Low-emission shipping – hydrogen/ammonia combustion, hydrogen fuel cell, battery electric

Low-emission aviation – hydrogen/ammonia/synthetic hydrocarbon combustion, hydrogen fuel cell, battery electric, limiting aviation demand increase.

LO3 **Examine how net zero energy technologies interact with energy demand and social practice**

Energy demand and social practice changes for net zero:

Travel behaviour

Heating and cooling behaviour

Dietary behaviour and impacts on energy systems

Social license and changing energy demand.

Interactions of energy demand and social practice with the energy system:

Demand reduction

Electricity demand flexibility

Digitalisation and energy-as-a-service.

LO4 **Analyse the suitability of different energy technologies in decarbonising energy demand in given geographical and socio-economic contexts.**

Factors that influence geographical and socio-economic contexts:

Demand for energy services around the world

The importance of geopolitics

Energy economics

Climate

Land use.

Factors that determine technology suitability:

Cost

Required infrastructure (e.g. hydrogen networks, electricity networks, rail/road infrastructure)

Existing systems (e.g. existing electricity networks, gas networks, existing industry)

Regulation (e.g. building regulations, emissions regulations for transport).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss the fundamentals of energy systems, demarcating supply, demand, and energy system infrastructure		**D1** Evaluate the impact that changes to particular sectors of the energy system have on others, including calculations and assessments of energy conversion efficiencies and the need to use systems thinking for the energy system as a whole.
P1 Discuss energy conversion processes in terms of the principles of energy conversion and comparisons of their efficiencies. **P2** Interpret Sankey diagrams to represent flows of energy and conversion between vectors.	**M1** Analyse how energy systems have evolved to provide for changing demand for energy services and the need to decarbonise the energy system.	
LO2 Explain how key net zero energy technologies work across key sectors of energy demand		**D2** Critically evaluate recent and ongoing trends in energy technologies and how evolving technology and costs might influence how these technologies are implemented.
P3 Explain the operating principle of each technology option in decarbonising energy demand across heating and cooling, transport, and use of electricity.	**M2** Analyse the key differences between technologies in a given sector in terms of operating efficiencies and costs, including reasons for these differences.	

Pass	Merit	Distinction
LO3 Examine how net zero energy technologies interact with energy demand and social practice		**D3** Justify how different demand behaviours in different geographical and socio-economic contexts can influence the suitability of different energy technologies in delivering net zero targets.
P4 Examine the influence of social practice and energy demand behaviour on energy technologies and energy system infrastructure.	**M3** Discuss, using specific examples, the varying levels of social license required for the net zero energy transition and how this varies by energy technology (for example: smart EV charging vs. reduction in flying).	
LO4 Analyse the suitability of different energy technologies in decarbonising energy demand in given geographical and socio-economic contexts.		**D4** Evaluate the benefits of different energy technologies in decarbonising energy demand with respect to cost, the environment, emissions and health.
P5 Analyse factors that influence differences in given geographical and socio-economic contexts with respect to the operating principles of energy technologies.	**M4** Assess the suitability of options available to decarbonise energy demand in developing potential pathways to net zero.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Berners-Lee, M. (2019) *There is no Planet B: A Handbook for the Make or Break Years*. Cambridge University Press.

Dixon, J., Brush, S., Fleet, G., Bell, K. and Kelly, N. (2021) *Energy Technologies for Net Zero.* The Institution of Engineering and Technology (IET).

MacKay, D.J.C. (2008) *Sustainable Energy – Without the Hot Air*. UIT Cambridge.

Sharma N. and Kumar P.D. (2023) *Towards Net-Zero Targets: Usage of Data Science for Long-Term Sustainability Pathways – Advances in Sustainability Science and Technology (Paperback).* Springer.

Zipse O., Hornegger J., Becker T., Beckmann M., Bengsch M., Feige I. and Schober M. (Editors) (2023) *Road to Net Zero: Strategic Pathways for Sustainability-Driven Business Transformation (Hardback).* Springer.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Baik, E., Chawla, K.P., Jenkins, J.D., et al. (2021) What is different about different net-zero carbon electricity systems? *Energy and Climate Change*, 2, 100046.

Bataille, C., Waisman, H., Briand, Y., et al. (2020) Net-zero deep decarbonization pathways in Latin America: Challenges and opportunities. *Energy Strategy Reviews*, 30, 100510.

DeAngelo, J., Azevedo, I., Bistline, J., et al. (2021) Energy systems in scenarios at net-zero CO_2 emissions. *Nature Communications*, 12(1), 6096.

Dixon, J., Bell, K. and Brush, S. (2022) Which way to net zero? A comparative analysis of seven UK 2050 decarbonisation pathways. *Renewable and Sustainable Energy Transition*, 2, 100016.

Links

This unit links to the following related units:

Unit 4005: Renewable Energy

Unit 4073: Sustainability and the Environment in the Manufacturing Industry

Unit 5018: Sustainability

Unit 5045: Electrical Engineering and Sustainability

Unit 5054: Net Zero Energy Technologies II: Infrastructure and Pathways.

Unit 4090: Engineering Science II

Unit Code: **M/650/9509**

Level: **4**

Credits: **15**

Introduction

Engineering is a discipline that uses scientific theory to design, develop or maintain structures, machines, systems and processes. Engineers are therefore required to have a broad knowledge of the science and application skills relevant to the industry around them.

This unit will complement *Unit 4003: Engineering Science I* by introducing advanced laws and applications of the physical sciences and how to apply knowledge and skills to find solutions to a variety of challenging engineering problems. *Unit 4003* is the recommended prerequisite or co-requisite for this unit.

The topics covered in this unit include stress and strain analysis, two-dimensional and rigid body dynamics, fracture mechanics and fatigue, and electrical measurement instruments and circuit simulation.

On successful completion of this unit, students will be able to interpret and present qualitative and quantitative data using computer software, calculate unknown parameters within mechanical systems in static and motion, explain advanced material properties, examine electrical measurement techniques and simulate circuits/systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate engineering structures and machine components in mechanical systems

LO2 Examine kinetics and kinematics of different dynamic systems

LO3 Explore material properties, material testing and failure analysis

LO4 Analyse different electrical circuits and systems.

Essential Content

LO1 **Investigate engineering structures and machine components in mechanical systems**

Statics and mechanics of materials:

Pin-jointed frames

Frames and machines

Normal stress and strain

Hooke’s law and Young’s modulus

Stress in members of a structure

Design stress analysis

Deformation under axial load

Poisson’s ratio and multiaxial loading

Stress concentration.

LO2 **Examine kinetics and kinematics of different dynamic systems**

Dynamics:

Two-dimensional particle kinematics

Plane kinematics of rigid bodies

Two-dimensional particle kinetics

Plane kinetics of rigid bodies

Impact and momentum.

LO3 **Explore material properties, material testing and failure analysis**

Engineering materials:

Metallurgy of alloying

Properties of metals

Ceramics, composites and polymers

Alternative engineering materials

Fracture mechanics

Fatigue and deformation

Corrosion and protection against it.

LO4 **Analyse different electrical circuits and systems**

Capacitance:

Charge

Electrical field

Dielectric constant

Applications (e.g. smoothing, blocking, coupling, filtering)

Associated formula e.g.

$$E = \frac{F}{Q} \qquad E = \frac{V}{d} \qquad C = \frac{\varepsilon A}{d} \qquad E\ (Energy) = \frac{QV}{2}$$

Circuits/systems:

For example: Amplifiers

Comparators

Power supplies

Oscillators

Analogue-to-digital converters (ADCs)

Digital-to-analogue converters (DACs)

Adders

Subtractors

Code generators.

Measurement techniques and instruments:

Voltmeters

Current meters

Signal generators

Oscilloscopes

Voltage measurement

Current measurement

Waveform display.

Circuit simulation:

Use of software packages (e.g. Multisim).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate engineering structures and machine components		**D1** Evaluate the deformation of mechanical systems.
P1 Calculate the forces in pin-joint structures. **P2** Investigate the forces in frames. **P3** Apply stress and strain analysis in the members of mechanical structures.	**M1** Determine the multiaxial stress and deformation by using Poisson's ratio.	
LO2 Examine kinetics and kinematics of different dynamic systems		**D2** Critically analyse plane kinetics and kinematics of rigid bodies.
P4 Apply the principles of Newton's laws of motion for two-dimensional particle kinematics. **P5** Examine the plane kinematics of rigid bodies.	**M2** Apply the principles of Newton's laws of motion for two-dimensional particle kinetics.	
LO3 Explore material properties, material testing and failure analysis		**D3** Justify materials selection based on the engineering needs or performance criteria for a specific application.
P6 Explore the common processing methodologies for metals, polymers and ceramics. **P7** Analyse the mechanisms of corrosion.	**M3** Determine alternative engineering materials for corrosion protection.	
LO4 Analyse different electrical circuits and systems		**D4** Critically analyse a range of electrical circuits/systems, including comparison of key measurements taken with equivalent software-simulated circuits/systems, with justification.
P8 Analyse the function of a capacitor, stating typical applications and calculating associated parameters. **P9** Demonstrate how typical items of test equipment would be used to undertake various measurements.	**M4** Justify itinerary of testing equipment and suitable alternatives to conduct measurements.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashby, M.F. and Jones, D.R.H. (2018) *Engineering Materials 1: An Introduction to Properties, Applications and Design.* 5th Ed. Oxford: Butterworth-Heinemann.

Beer, F.P., DeWolf, J.T., Mazurek, D. and Johnston, J.T. (2019). *Mechanics of Materials ISE.* 8th Ed. London: McGraw-Hill Education.

Bird, J. (2022) *Bird's Electrical Circuit Theory and Technology.* 7th Ed. Abingdon: Routledge.

Hayt, W.H., Kemmerly, J., Phillips, J. and Durbin, S.M. (2023) *Engineering Circuit Analysis ISE.* 10th Ed. London: McGraw-Hill Education.

Hibbeler, R.C. (2016) *Engineering Mechanics: Dynamics.* 14th Ed. Harlow: Pearson.

Hibbeler, R.C. (2017) *Engineering Mechanics: Statics.* 14th Ed. Harlow: Pearson.

Hibbeler, R.C. (2023) *Mechanics of Materials, SI Edition.* 11th Ed. Harlow: Pearson.

Kulp, C.W. and Pagonis, V. (2021) *Classical Mechanics: A Computational Approach with Examples Using Mathematica and Python.* Abingdon: CRC Press.

Rauf, S.B (2022) *Electrical Engineering for Non-Electrical Engineers.* 3rd Ed. Gistrup, Denmark: River Publishers.

Tripathi, S.L., Alvi P.A. and Subramaniam, U. (2021) *Electrical and Electronic Devices, Circuits and Materials.* Boca Raton, Florida: CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Advanced Science

Applications in Engineering Science

Engineering Reports

International Journal of Engineering Science

International Journal of Engineering Technology and Scientific Innovation

PLOS ONE

Science Advances

Scientific Reports

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4003: Engineering Science I

Unit 4009: Materials, Properties and Testing.

Unit 4091: Automotive Fundamentals

Unit Code: M/651/3044
Level: 4
Credits: 15

Introduction

Automotive engineering fundamentals, rooted in mechanical engineering, electronics, materials science and, increasingly, software development, are crucial across its different specialisms such as motorsport, heavy vehicles and motorcycles. The industry's shift towards electrification demands innovation in battery technology, electric drivetrains and energy recovery systems to support sustainable practices. In motorsport, the focus is on high performance, speed and reliability, with advances in engine power and aerodynamics to reduce drag and enhance stability. Heavy vehicle engineering prioritises durability, fuel efficiency, and load capacity, often improving drivetrains and suspension systems for better handling and safety. Motorcycle engineering addresses the unique dynamics of two-wheeled vehicles, requiring advanced electronics to mitigate road condition risks. Each sector presents distinct challenges, necessitating specialised expertise to optimise vehicle design and functionality, whether for racing, load transport or everyday commuting. As technology evolves, so does the role of the automotive engineer, continually enhancing vehicle performance and integrating new technologies.

The aim of this unit is to provide a comprehensive overview of the fundamental principles and practices underpinning the design, manufacture, maintenance and repair of automobiles. Students will explore the key stages of the automotive lifecycle, key components of automotive vehicles, design processes, prototyping and quality assurance. The unit supports students aspiring to become automotive engineers, technicians or enthusiasts, equipping them with the knowledge, skills and behaviours necessary to understand and engage with all aspects of automotive technology.

Topics covered include: the key stages of the automotive lifecycle, from initial design and development through to manufacture; processes involved in creating vehicles, from concept ideation and prototyping to mass production and quality assurance; and four fundamental areas of automotive design, namely, body and structures, chassis and dynamics, propulsion systems, and electrical and electronic systems.

By the end of this unit, students will have acquired a solid base in automotive fundamentals, as well as a comprehensive understanding of the processes and technologies driving the automotive industry forward. Students will appreciate automotive vehicle design, manufacturing, maintenance or repair, and will gain the knowledge and skills necessary to embark on a rewarding career in the automotive sector across automotive, motorsport, heavy vehicle and motorcycle industries.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Review automotive vehicle design and principles with regards to chassis systems and crash structures

LO2 Apply engineering principles to solve real-world automotive engineering problems with regards to suspension, steering and braking systems

LO3 Describe the function and operation of vehicle propulsion systems

LO4 Discuss an appropriate electronic system for an automotive powertrain.

Essential Content

LO1 **Review automotive vehicle design and principles with regards to chassis systems and crash structures**

Sector overview:

Current and emerging automotive technologies

Global and regional needs and trends

Knowledge, skills, and behaviours of a selection of occupations and standards (e.g. engineering manufacturing technician, lead engineering maintenance technician)

Professional bodies and roles (e.g. incorporated engineer, chartered engineer)

Careers in automotive sector.

Automotive fundamentals:

Key stages of automotive lifecycle: ideation, design, prototyping to manufacturing, quality assurance

Fundamental areas of automotive design: body and structures, chassis and dynamics, propulsion systems, and electrical and electronic systems.

Chassis types:

Automotive passenger vehicle chassis types and construction

Motorsport chassis types and construction

Heavy vehicle chassis types and construction

Motorcycle chassis types and construction

The design and construction of vehicle bodies and structures.

Materials:

Materials selection for various chassis and body types

Bonding and joining of materials

Interaction of various material types

Materials science: composites, alloys and metals.

Crash structures:

Material elasticity and failure

Passenger protection zones

Pedestrian protection zones

Design and safety features of collapsible structures including engine mounts, steering columns and pedal boxes.

Manufacturing techniques and applications:

Manufacturing processes: casting, forming and shaping

The machining or rapid prototype/manufacture of components

Additive manufacturing technologies

Joining of materials such as welding, brazing, soldering, adhesive bonding and mechanical joints; production methods (e.g. single, batch, flow and mass)

The role of sustainability and environmental efficiency in decision-making

Industry 4.0 for the automotive sector: concepts and its impact on organisations, including the integration of automation, digital systems and manufacturing engineering systems.

Documentation methods and techniques:

Job cards/build records, 2D and 3D drawing/models, bill of materials (BoM), cost analysis reports, compliance report, standard operating instructions (SOIs), standard process instructions (POIs), engineering query notifications (EQNs) and drawing query notifications (DQNs)

Use of data collection systems, data formats and dashboards; secondary and primary data should be critiqued and considered with an objective mindset

Financial literacy and documentation: planning, recording and review processes and documentation such as departmental budgets, estimating, cost control, cost forecasting and investment appraisal.

LO2 **Apply engineering principles to solve real-world automotive engineering problems with regards to suspension, steering and braking systems**

Vehicle layouts:

Drive systems and location of major components in vehicles, including heavy vehicles, road vehicles, motorsport vehicles and motorcycles

Vehicle architecture and their effect on mass, centre of gravity and size of vehicle.

Braking, suspension and steering systems:

Braking systems and appropriate sizing of components for braking performance on all vehicle types

Typical on- and off-road vehicle suspension systems and electronic aids

Motorsport suspension systems and additional adjustments compared with road vehicles

Typical heavy vehicle suspension systems

Motorcycle suspension and adjustments

Various steering mechanisms and how they differ depending on application and vehicle type.

Dynamics:

Chassis design and the impact on dynamics

Camber, toe, castor and their effects on vehicle handling characteristics

Centre of gravity, vehicle mass and the effects on suspension design and vehicle behaviour

Mathematical formulae for spring and damper rates.

Industry case studies:

Real-world automotive problems and examples of good practice

Sustainable solutions

Legislation for mass production appropriate to country of manufacture and target market.

Safety first culture in workshops:

Local workshop context, layout, documentation, checklists including working appropriately and safely

Regulations, policies, procedures and practices, compliance, quality safety systems of work, sharing good practice.

Human factors:

Impact of human factors (i.e. organisational, environment and job factors) on individual/team behaviours and performance.

LO3 **Describe the function and operation of vehicle propulsion systems**

Internal combustion engines:

Spark-ignition and compression ignition engine cycles

2-stroke and 4-stroke engines

Pressure volume (PV) diagrams

Volumetric efficiency

Fuel and combustion.

Electric and hybrid powertrains:

Electric motors and operating principles

Hybrid vehicles and layouts; electric vehicle and layouts

Charging types including PHEV, BEV, HEV, charge regeneration types

State of charge and driving modes.

Transmission systems:

Transmission systems and layouts for front- wheel drive, rear-wheel drive and four-wheel drive

Automatic transmission systems, manual transmission systems, advanced transmission systems e.g. PDK

Hybrid and electric vehicle transmission systems including CVT.

LO4 **Discuss an appropriate electronic system for an automotive powertrain**

Electrical systems:

Wiring harnesses: Ohm's law, appropriate selection of wiring and construction, reading of wiring diagrams

Sensors and actuators: operating parameters and selection of sensor and actuator types

Starting and charging systems

Body and engine electrical systems.

Electronic systems:

Control units for vehicle body, chassis, engine and transmission

Communication techniques between control units

CAN and ISO bus: hierarchy of information signals

ROM/RAM and reprogramming

Engineer access and interrogation of electronic systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Review automotive vehicle design and principles with regards to chassis systems and crash structures		**LO1 and LO2**
P1 Review the function of a vehicle chassis. **P2** Examine two different body types for an appropriate application.	**M1** Determine the appropriate material and failure rate for a crash structure.	**D1** Justify the design of a vehicle braking, chassis, steering and suspension layout for a specific type of vehicle.
LO2 Apply engineering principles to solve real-world automotive engineering problems with regards to suspension, steering and braking systems		
P3 Discuss appropriate braking and suspension components for a specific type of vehicle. **P4** Apply steering and suspension geometry to study vehicle handling for a specific type of vehicle.	**M2** Calculate spring rates, damper rates, critical damping rates, damping ratios and centre of gravity location for a specific vehicle's operating environment.	

Pass	Merit	Distinction
LO3 Describe the function and operation of vehicle propulsion systems		**LO3 and LO4**
P5 Describe the design, function and efficiency of the two- and four-stroke cycle for all fuel types. **P6** Determine the difference in power and torque generation between an internal combustion engine and an electric motor.	**M3** Assess the effectiveness of a four-wheel drive hybrid system powertrain layout.	**D2** Justify the design of a hybrid powertrain electronic system for a specific vehicle including how it will communicate to other systems.
LO4 Discuss an appropriate electronic system for an automotive powertrain		
P7 Discuss the function of sensors fitted to vehicles. **P8** Determine the function of actuators fitted to vehicles.	**M4** Assess communication techniques between control units on a specific vehicle.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Denton, T. (2020) *Advanced Automotive Fault Diagnosis: Automotive Technology: Vehicle Maintenance and Repair.* 5th Ed. Oxon: Routledge.

Denton, T. (2022) *Automobile Mechanical and Electrical Systems.* 3rd Ed. Oxon: Routledge.

Denton, T. (2020) *Electric and Hybrid Vehicles*. 2nd Ed. Oxon: Routledge.

Gillespie, T.D. (2021) *Fundamentals of Vehicle Dynamics.* Revised Ed. Warrendale: SAE International.

Husain, I. (2021) *Electric and Hybrid Vehicles: Design Fundamentals*. 3rd Ed. Oxon: CRC Press.

Livesey, A. (2021) *Motorcycle Engineering.* Oxon: Routledge.

Livesey, A. (2019) *Practical Motorsport Engineering.* Oxon: Routledge.

Lot, R. and Sadauckas, J. *Motorcycle Design: Vehicle Dynamics Concepts and Applications*.

Nunney, M.J. (2006) *Light and Heavy Vehicle Technology*. Oxon: Routledge.

Pistoia, G. and Liaw, B. (2018) *Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost (Green Energy and Technology)*. Switzerland: Springer.

Quarto, M. and Goodnight N. (2022) *Light Duty Hybrid and Electric Vehicles. (Master Automotive Technician)*. Massachusetts: Jones & Bartlett Publishers.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Balena, M., Mantriota, G. and Reina, G. (2021) 'Dynamic handling characterization and set-up optimization for a Formula SAE race car via multi-body simulation', *Machines*, 9(126), pp. 1–26.

D'amore, L., Costa, D. and Messagie, M. (2024) 'Economic and environmental assessment of technologies optimizing the execution of long trips for electric vehicles', *World Electric Vehicle Journal*, 15, pp. 128. Available at: https://doi.org/10.3390/wevj15040128

Links

This unit links to the following related units:

Unit 4097: Electric Vehicle Battery Manufacture

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 4093: Race Car Design and Manufacturing

Unit 5060: Motorsport Workshop Preparation and Inspection

Unit 4096: Automotive Workshop Practices.

Unit 4092: Vehicle Dynamics and Performance

Unit Code: R/651/3045

Level: 4

Credits: 15

Introduction

Vehicle dynamics and performance are crucial in automotive engineering, impacting handling, safety, comfort and efficiency. This field involves analysing vehicle chassis, tyres, suspension and steering systems to enhance vehicle stability and ride quality. Professionals, including vehicle dynamics engineers, performance analysts and technicians, are essential for advancing automotive technology to meet safety and efficiency standards and contribute to innovations such as active suspension and advanced driver assistance systems (ADAS). These roles ensure that vehicles are designed, tested and maintained to the highest performance criteria.

The aim of this unit is to introduce the fundamental laws and applications of vehicle dynamics and to apply knowledge and skills to find solutions to a variety of vehicle performance problems. Students will learn both the mathematical and practical aspects of vehicle dynamics for effective concept design, system analysis and handling development. The main building blocks for understanding vehicle dynamics, which this unit aims to develop, include the essentials of dynamics, steering systems, and suspension functions.

Unit 4003 Engineering Science I is the recommended pre-/co-requisite for this unit.

Among the topics included in this unit are vehicle dynamics and tyres, the theory of particle and rigid body kinetics and kinematics, 1DOF vehicle dynamic analysis, and steering and suspension system fundamentals.

Upon successful completion of this unit, students will be able to interpret and present qualitative and quantitative data on vehicle dynamics, calculate unknown parameters within vehicle systems, explain various tyre properties, examine the kinetics and kinematics of vehicle systems, and analyse suspension and steering systems.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Investigate vehicle dynamics and tyre performance

LO2 Apply the theory of particle and rigid body kinetics and kinematics in dynamic systems

LO3 Examine the vehicle dynamic performance for one-dimensional and planar analysis

LO4 Analyse the functioning of steering and suspension systems.

Essential Content

LO1 **Investigate vehicle dynamics and tyre performance**

Vehicle mechanics:

Units and quantities: application to practical scenarios in vehicle mechanics

Introduction to vehicle mathematical modelling: used to represent vehicle dynamics, models for predicting longitudinal and lateral dynamics of a vehicle under various conditions

Vehicle classifications (e.g. passenger cars, trucks, motorcycles)

Role of quality management systems e.g. ISO9001, ISO 14001, ISO45001 and TS16949; other region-specific industry standards; application of regulatory and safety standards governing vehicle design and performance; compliance

Vehicle powertrain, body and chassis; interaction between components to influence overall vehicle performance

Whole vehicle performance, comfort and the measurement methods

Special features and differences of passenger car, motorcycle and truck/bus dynamics.

Tyre properties and performance:

Tyre construction: materials and methods used in tyre manufacturing

Radial and non-radial tyres

Tyres and sidewall information (size, load rating, speed rating),
tyre selection criteria for specific vehicles

Wheel and rim

Essential concepts of tyre mathematical modelling

Tyre slip and generation of forces from the slip

The Coulomb friction model

The friction circle

Limiting frictional force

Other tyre properties relevant to example industry case studies.

LO2 **Apply the theory of particle and rigid body kinetics and kinematics in dynamic systems**

Free body diagrams:

Centre of gravity and centrifugal force: vehicle stability and handling during cornering, application of concepts in vehicle design and performance

Equilibrium of longitudinal forces, equilibrium of lateral forces and equilibrium of moments around the vehicle's vertical axis

Two-dimensional particle kinematics and the equations of a planar vehicle moment

Plane kinematics of rigid bodies

Two-dimensional particle kinetics

Plane kinetics of rigid bodies

Mechanisms and machine dynamics.

LO3 **Examine the vehicle dynamic performance for one-dimensional and planar analysis**

One-dimensional vehicle dynamics:

Tractive force and tractive resistance

Newtonian versus D'Alembert's approach

Stationary vehicle or moving at constant velocity on a level road

Stationary vehicle or moving at constant velocity car on an inclined road (e.g. with or without a trailer as an example case)

Stationary vehicle or moving at constant velocity car on a banked road

Accelerating/decelerating on a level road

Accelerating/decelerating on an inclined road

Rear-wheel, front wheel and four-wheel drive vehicles.

Vehicle planar dynamics:

Coordinate systems

Rigid vehicle dynamics

Tyre force and body force systems

Tyre lateral force

Rigid body load transfer effects for straight line motion

Rigid body load transfer effects during cornering.

LO4 **Analyse the functioning of steering and suspension systems**

Steering systems:

Steering system fundamentals and vehicle handling performance

General design requirements of the steering systems, safety standards and regulations

Rack and pinion

Steering box systems

Hydraulic power assisted steering

Electric power assisted steering

Steering by wire

Steering ratio

Kinematic steering and steering geometry

Understeer, oversteer and roll characteristics

Vehicle yaw, yaw rate, body slip angle

The trend towards big, tall SUVs and roll characteristics

Understeer in modern vehicle design.

Suspension systems:

Role of a vehicle suspension

Suspension system components

Solid axle suspension, torsion beam trailing-arms suspension, the push-rod and pull-rod suspensions

Independent suspension

Roll centre and roll axis

Tyre relative angles: toe, caster angle, camber and trust angle

Kinematic analysis of suspensions.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Investigate vehicle dynamics and tyre performance</td><td rowspan="5">LO1 and LO2

D1 Analyse plane kinetics and kinematics of rigid bodies.</td></tr>
<tr><td>P1 Discuss the key components of the powertrain and chassis system.

P2 Investigate the tyre properties and sidewall information for a given vehicle.</td><td>M1 Analyse the friction circle and limiting frictional force.</td></tr>
<tr><td colspan="2">LO2 Apply the theory of particle and rigid body kinetics and kinematics in dynamic systems</td></tr>
<tr><td>P3 Apply the principles of Newton’s laws for two-dimensional particle kinematics.

P4 Examine the plane kinematics of rigid bodies.</td><td>M2 Apply the principles of Newton’s laws for the equilibrium of forces and moments in two-dimensional particle kinetics.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Examine the vehicle dynamic performance for one-dimensional and planar analysis		**LO3 and LO4**
P5 Evaluate the vehicle dynamic performance D'Alembert's theory. **P6** Examine the kinematic steering characteristics of a vehicle.	**M3** Apply the load transfer effects on a vehicle during cornering.	**D2** Evaluate the kinematics of a suspension system for a case-study vehicle.
LO4 Analyse the functioning of steering and suspension systems		
P7 Specify different components of a suspension system. **P8** Analyse the relative angles of the tyre and their impact on the vehicle's overall performance.	**M4** Determine the roll centre and roll axis for a selected case.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Abe, M. and McPhee, J. (2020) *Vehicle Handling Dynamics: Theory and Application*. 3rd Ed. Oxford: Butterworth-Heinemann.

Barton, D. and Fieldhouse, J. (2024) Automotive Chassis Engineering. 2nd Ed. Springer.

Blundell, M. and Harty, D. (2014) *The Multibody Systems Approach to Vehicle Dynamics*. 2nd Ed. Elsevier.

Gillespie, T. (2021) *Fundamentals of Vehicle Dynamics*. SAE International.

Jazar, R. (2017) *Vehicle Dynamics: Theory and Application*. 3rd Ed. Springer.

Milliken, W.F. and Milliken, D.L. (2021) *Race Car Vehicle Dynamics*. 3rd Ed.

Mitschke, M. and Wallentowitz, H. (2021) Dynamik der Kraftfahrzeuge. 5th Ed. Berlin: Springer Vieweg.

Pacejka, H.B. (2021) *Tire and Vehicle Dynamics*. 4th Ed. Oxford: Butterworth-Heinemann.

Rajamani, R. (2022) *Vehicle Dynamics and Control*. 3rd Ed. New York: Springer. Warrendale, PA: SAE International.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Jin, X., Yin, G. and Chen, N. (2019) 'Advanced estimation techniques for vehicle system dynamic state: A survey', *Sensors*.

Yang, S., Lu, Y. and Li, S. (2013) 'An overview on vehicle dynamics', *International Journal of Dynamics and Control*, 1(4), pp. 385–395.

Zha, Y., Deng, J., Qiu, Y., Zhang, K. and Wang, Y. (2023) 'A survey of intelligent driving vehicle trajectory tracking based on vehicle dynamics', *SAE International Journal of Vehicle Dynamics, Stability, and NVH*, 7, pp. 221–248.

International Journal of Vehicle Design. Available at: https://www.inderscience.com/jhome.php?jcode=ijvd.

Journal of Automotive Engineering. Available at: https://journals.sagepub.com/home/jae.

Journal of Vehicle Dynamics, Stability, and NVH. Available at: https://www.sae.org/publications/collections/content/E-JOURNAL-10/.

Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. Available at: https://journals.sagepub.com/home/pia.

Vehicle System Dynamics. Available at: https://www.tandfonline.com/journals/nvsd20.

Links

This unit links to the following related units:

Unit 4002: Engineering Mathematics

Unit 4003: Engineering Science I

Unit 4063: Engineering Mechanics and Materials

Unit 4093: Race Car Design and Manufacturing

Unit Code: T/651/3046

Level: 4

Credits: 15

Introduction

Race car design and manufacturing is an intricate and highly specialised field within automotive engineering, focusing on the development of high-performance vehicles for competitive racing on the track. This industry demands a combination of advanced engineering skills, innovative design techniques, and cutting-edge manufacturing processes to design cars that can perform at extreme levels of speed and efficiency. Globally, notable companies like Ferrari, McLaren, Audi and Toyota lead in Formula 1 and endurance racing, showcasing the industry's blend of innovation and excitement, while significantly influencing research and development in broader automotive technologies. This field facilitates numerous career opportunities ranging from aerodynamicists and materials engineers to data analysts and race strategists.

The aim of this unit is to equip students with the knowledge skills and behaviours necessary to conceptualise, design and manufacture race cars. Future careers of a race car engineer, a team manager or a technician in the motorsport industry begins with a solid foundation. This unit enables students to pursue their passion and to make their mark in the competitive world of racing. Throughout this unit, students will delve into the key principles of vehicle dynamics and mechanical engineering, gaining insight into how these factors influence the performance and handling of race cars. Additionally, students will explore advanced manufacturing processes and materials used in race car construction, including composite materials, additive manufacturing techniques and rapid prototyping methods.

The unit places a strong emphasis on safety, recognising the paramount importance of protecting drivers and personnel involved in motorsport events. Students will learn about the latest safety standards and regulations governing race car design, and strategies for implementing effective safety measures without compromising performance.

On successful completion of this unit, students will have achieved a comprehensive understanding of race car design and manufacturing principles, and the practical skills necessary to apply this knowledge in real-world racing scenarios.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Demonstrate the fundamental principles of race car design

LO2 Demonstrate the ability to translate design concepts into physical prototypes and production-ready components by describing state-of-the-art manufacturing technologies, and appropriate selection of materials

LO3 Implement effective safety measures and features in race car designs without compromising performance or agility on the track

LO4 Apply theoretical knowledge to design concepts, manufacturing processes and safety considerations for a race car design.

Essential Content

LO1 **Demonstrate the fundamental principles of race car design**

Chassis and body:

Vehicle chassis designs, evolution, concepts and mountings, including space frames, monocoque chassis, structural considerations and materials

Drive train layouts

Centre of gravity, track and wheelbase

Introduction to aerodynamics, downforce, drag and aerodynamic components utilised on race vehicles

Powertrain including transmission systems, principles of design and operation of gearboxes, clutches, differentials and power supply.

Suspension and steering systems:

Dampers and springs, 2-way and 4-way adjustable suspension

Principles of design for suspension geometry and calculation for spring and damper forces

Steering mechanisms and applications

Comparison of different tyres and compounds.

Mechanical engineering:

Component design and space constraints

Nuts, bolts and fasteners

Appropriate methods of retaining fasteners and ensuring restraint of components

Vehicle dynamics, high-performance racing vehicles.

LO2 **Demonstrate the ability to translate design concepts into physical prototypes and production-ready components by describing state-of-the-art manufacturing technologies, and appropriate selection of materials**

Materials:

Selection of materials: types of materials for race car design; use cases and trends in using alloys, metals, plastics and composites

Properties and requirements: physical and chemical properties, metallurgy and composition, component requirements and material constraints.

Failure analysis:

Mathematical analysis of materials and forces applied to motorsport components

Life cycles of components and the need for component age databases

Race car design constraints including physical and technical regulation constraints based on rules and regulations for particular race series

Failure analysis including use of software.

Manufacturing techniques and applications:

Manufacturing processes: casting, forming and shaping

The machining or rapid prototype/manufacture of components

Additive manufacturing technologies

Joining of materials such as welding, brazing, soldering, adhesive bonding and mechanical joints; production methods (e.g. single, batch, flow and mass)

The role of sustainability and environmental efficiency in decision-making

Industry 4.0 for the automotive sector – concepts and its impact on organisations, including the integration of automation, digital systems and manufacturing engineering systems.

Documentation methods and techniques:

Job cards/build records, 2D and 3D drawing/models, bill of materials (BoM), cost analysis reports, compliance report, standard operating instructions (SOIs), standard process instructions (POIs), engineering query notifications (EQNs) and drawing query notifications (DQNs)

Use of data collection systems, data formats and dashboards; secondary and primary data should be critiqued and considered with an objective mindset

Financial literacy and documentation: planning, recording and review processes and documentation e.g. departmental budgets, estimating, cost control, cost forecasting and investment appraisal.

LO3 **Implement effective safety measures and features in race car designs without compromising performance or agility on the track**

Vehicle design:

Chassis strength

Design considerations for areas of strength and for areas to deform or absorb impacts

Mass and weight considerations and location of mass for vehicle performance and handling characteristics

Crashworthiness, impact attenuation

Comparison of race vehicle designs and specific race rules and regulations.

Driver protection:

Safety considerations

Safety aspects included and mandatory in specific race rules and regulations

Fire safety and fire systems

Driver protection including driver race wear and PPE

Roll cages and materials

Fast extraction design considerations for drivers after an accident.

LO4 **Apply theoretical knowledge to design concepts, manufacturing processes and safety considerations for a race car design**

The complete race car:

Design considerations when taking the race car as a whole

Amalgamation of several vehicle mechanical systems and safety systems to influence a development path for performance

Using specific race cars as a design consideration, identify components and evaluate a redesign or analyse why they are designed in a particular way.

Presentation:

Cross-departmental communication of ideas and concepts clearly and persuasively

Justification of design concepts

Justification of material selection

Presentation of results software simulations and preparing documentation in appropriate formats to a wider audience or separate departments.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Demonstrate the fundamental principles of race car design		**LO1 and LO2**
P1 Demonstrate knowledge of the mechanical systems of a race vehicle. **P2** Determine aerodynamic components of a race vehicle.	**M1** Explain methods of fastening to effectively restrain components to a race vehicle.	**D1** Simulate a multi-section assembly of a race vehicle to justify the design concept.
LO2 Demonstrate the ability to translate design concepts into physical prototypes and production-ready components by describing state-of-the-art manufacturing technologies, and appropriate selection of materials		
P3 Demonstrate knowledge of typical materials used within race vehicle design. **P4** Determine appropriate manufacturing techniques used within race vehicle design.	**M2** Justify selection of appropriate materials for at least two race vehicle components.	

Pass	Merit	Distinction
LO3 Implement effective safety measures and features in race car designs without compromising performance or agility on the track		**LO3 and LO4**
P5 Implement any two safety measures on a race vehicle for a given scenario. **P6** Analyse safety measures with regards to driver safety and PPE.	**M3** Evaluate strength and mass of components and how they affect race car safety and performance.	**D2** Present evaluation of the design concept of a safety-specific component with respect to international safety standards to target audiences.
LO4 Apply theoretical knowledge to design concepts, manufacturing processes and safety considerations for a race car design		
P7 Apply knowledge and skills to analyse the design of a component with reference to specific race rules and regulations. **P8** Explain the manufacturing process of a component, specifically designed to improve vehicle performance and safety.	**M4** Create a design specification document suitable for cross-departmental sharing.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Barbieri, G. (2023) *Automotive Suspension.* Italy: Le Penseur.

Ferguson, D. (2019) *The Science of Motorsport.* Oxon: Routledge.

Livesey, A. (2019) *Practical Motorsport Engineering.* Oxon: Routledge.

Seward, D. (2014) *Race Car Design*. Red Globe Press.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Saplinova, V. Novikov, I. and Glagolev, S. (2020) 'Design and specifications of racing car chassis as passive safety feature', *Transportation Research Procedia*, 50, pp. 591–607.

Links

This unit links to the following related units:

Unit 4094: Motorsport Workshop Practices

Unit 5060: Motorsport Workshop Preparation and Inspection

Unit 4094: Motorsport Workshop Practices

Unit Code: Y/651/3047

Level: 4

Credits: 15

Introduction

The intricacies of maintaining, tuning and optimising motorsport vehicles such as race cars for peak performance on the track essentially start in the workshop. From routine maintenance tasks to fine-tuning motorsport vehicle set-ups, and from hybrid vehicle technology to workshop safety protocols, a comprehensive knowledge of the core practices and procedures employed in the motorsport workshop environment is essential.

The aim of this unit is to enable students to dive into the heart of motorsport maintenance, covering suspension tuning, motorsport vehicle set-up for specific racetracks and ensuring the life of components is monitored and how it may be extended by maintenance. Students will gain hands-on experience in motorsport vehicle (e.g. race car) maintenance and set-up procedures.

Topics covered include: a strong emphasis on health and safety practices; recognising the importance of maintaining a safe and secure workshop environment for both personnel and motorsport vehicles; specific safety protocols and regulations governing motorsport workshops; general workshop health and safety guidelines applicable to automotive environments including how to work safely on a hybrid or electric motorsport vehicle such as a race car.

On successful completion of this unit, students will have acquired a solid foundation in motorsport workshop practices and will have the practical skills and knowledge necessary to perform maintenance, set-ups and safety procedures with confidence and proficiency.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Conduct routine maintenance and inspection tasks on motorsport vehicles

LO2 Apply diagnostic techniques and specialised tools and equipment to solve mechanical issues efficiently

LO3 Develop knowledge of motorsport vehicle set-up principles and different track layouts

LO4 Implement health and safety protocols and procedures in the workshop.

Essential Content

LO1 **Conduct routine maintenance and inspection tasks on motorsport vehicles**

Maintenance:

Routine maintenance and inspection of race vehicles: engine inspections, fluid changes and suspension adjustments

Typical fluid change intervals for race vehicles

Brake servicing and inspection including temperature cycles and measuring and recording of component wear

Suspension wear, leakages and rose joint bearing wear

Optimal performance and reliability on track.

Component lifespan:

Recording of component usage

Lifespan of components and ensuring effective changes to coincide with race season and race mileage

Oil inspection and testing.

Pre- and post-race inspection:

Pre- and post-race inspection or maintenance

Race weekend anomalies or changes to maintenance schedules

Improvements or changes to lifespan of components determined by routine maintenance or inspection

Critical wear.

LO2 **Apply diagnostic techniques and specialised tools and equipment to solve mechanical issues efficiently**

Diagnostic techniques:

Oil friction tester and oil analysis techniques; oil contamination

Specialised tools and test equipment: cylinder leakage tester, exhaust gas analyser, electronic meter, fuel pressure gauge, engine analyser, computer-based and telemetric devices

Electronic infiltration of systems to analyse data and identify wearing/break down of components

Crack testing

Visual and practical testing of components

Data logging for during and after event analysis

Data telemetry for live analysis.

Rectification:

Repair procedure and diagnosis justifications

Presentation of results and tests

Replacement or repair of motorsport vehicle components

Troubleshooting guidelines and manuals

Live demonstrations of troubleshooting

Relevant safety aspects and practices.

LO3 **Develop knowledge of motorsport vehicle set-up principles and different track layouts**

Motorsport vehicle handling parameters:

Caster, camber and toe

Ride heights

Corner weights

Damper adjustments and spring pre-loads and spring rates

Aerodynamic downforce and drag compromise, aerodynamic distribution.

Circuit architecture and vehicle behaviour:

High- and low-speed compression and rebound

Corner architecture and vehicle trajectory changes

Percentage of throttle to brake during a lap

High-speed and low-speed corners

Length of straight aways.

Practical set-up:

Motorsport vehicle set-up principles (e.g. race car specific) including alignment, weight distribution and aerodynamic adjustments.

Optimisation for handling and balancing

Set-up testing and tuning for various race circuits

Set-up sheets and how to record effective set-ups and changes

The effects of race car geometry set-up

Various track set-ups and why they differ; performance characteristics

Flat patch set-up.

LO4 **Implement health and safety protocols and procedures in the workshop**

Safety first culture in motorsport workshops:

Local workshop context, layout, documentation, checklists including working appropriately and safely

Regulations, policies, procedures and practices, compliance, quality safety systems of work, good practice

Accidents and injuries associated with hybrid and electric vehicles.

Disposal of waste and industry regulations:

ATEX and DSEAR

The Environmental Protection Act 1990

The Health and Safety at Work Act 1974

ISO standards

Race circuit waste disposal protocol.

Personal protective equipment (PPE):

Details of PPE including what is employer or employee responsibilities for provision and routine maintenance

Regular monitoring of PPE condition

Appropriate PPE for various work practices

Safety issues relating to working on race vehicles and incorrect use of PPE

Hazard and safety priorities when working on race vehicles including electric and hybrid race vehicles.

Tools and equipment:

Tools and equipment including electric machines used in an automotive workplace

Sage and correct handling and use of all tools and equipment

Training on use of certain tools

Appropriate safety considerations and tool usage on electric and hybrid race vehicles.

Human factors:

Impact of human factors (organisational, environment and job factors) on individual/team behaviours and performance.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Conduct routine maintenance and inspection tasks on motorsport vehicles		**LO1 and LO2**
P1 Conduct routine maintenance, servicing and inspection on a motorsport vehicle. **P2** Create a component lifespan inspection and recording document.	**M1** Implement critical inspections that should be carried out pre, during and post competition, for a given setting or scenario.	**D1** Create industry standard documentation that enables inspection, maintenance and preventative measures for a motorsport vehicle, for a full race season.
LO2 Apply diagnostic techniques and specialised tools and equipment to solve mechanical issues efficiently		
P3 Apply mechanical and visual equipment and techniques to diagnose typical race vehicle failures. **P4** Diagnose typical race vehicle failures using electronic devices and pre-empt vehicle or component failures.	**M2** Solve vehicle and component failures with justification for the chosen rectification technique/method.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Develop knowledge of motorsport vehicle set-up principles and different track layouts</td><td rowspan="4">LO3 and LO4
D2 Produce risk assessments for the workshop and pit-lane environment including working on hybrid and electric vehicles.</td></tr>
<tr><td>P5 Set up a flat patch and measuring instrumentation to enable race vehicle set-up.
P6 Develop at least two full motorsport vehicle set-ups for two race circuits of various architecture.</td><td>M3 Analyse set-up sheets to establish why race vehicle set-ups are circuit dependant.</td></tr>
<tr><td colspan="2">LO4 Implement health and safety protocols and procedures in the workshop</td></tr>
<tr><td>P7 Implement appropriate health and safety regulations for a given setting or scenario including disposal of hazardous substances.
P8 Propose safe working practices for typical hand tools and machines used in the motorsport workshop including appropriate PPE.</td><td>M4 Analyse typical accidents and injuries that may occur when working on hybrid and electric motorsport vehicles.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Balkwill, J. (2018) *Performance Vehicle Dynamics: Engineering and Applications.* Oxford: Butterworth-Heinemann.

Bolles, R. (2019) *Race Car Technology Level 1.* Arizona: CRD Publishing.

Bolles, R. (2019) *Race Car Technology Level 2.* Arizona: CRD Publishing.

Bolles, R. (2019) *Race Car Technology Level 3.* Arizona: CRD Publishing.

Livesey, A. (2019) *Practical Motorsport Engineering.* Oxon: Routledge.

Gillespie, T.D. (2021) *Fundamentals of Vehicle Dynamics.* Revised Ed. Warrendale: SAE International.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Balena, M., Mantriota, G. and Reina, G. (2021) 'Dynamic handling characterization and set-up optimization for a Formula SAE race car via multi-body simulation', *Machines*, 9(126), pp. 1–26.

Links

This unit links to the following related units:

Unit 4093: Race Car Design and Manufacturing

Unit 5060: Motorsport Workshop Preparation and Inspection

Unit 4095: Automotive Combustion

Unit Code: A/651/3048

Level: 4

Credits: 15

Introduction

Key performance attributes such as torque, power, emissions, fuel consumption and efficiency, for which engines are often appraised, can be influenced by the combustion within the internal combustion (IC) engine. The understanding of combustion within an IC engine is beneficial to several disciplines and job roles within the automotive, motorsport, mechanical engineering and other cognate sector disciplines. Knowledge of how combustion occurs, factors that influence it and serviceability of combustion related systems can aid the developer of engine combustion systems as well as providing a depth of knowledge for the maintenance engineer.

The aim of this unit is to provide students with insight into the chemistry of the combustion process for rich, lean and stoichiometric air–fuel ratios. Students will explore combustion system design, fuel delivery methods and the impact these have on the process of combustion, as well as factors such as air-fuel mixture strength, ignition timing and diesel fuel injection timing that influence flame propagation, performance outcomes, emissions and abnormal combustion. Engine mechanical systems, related to combustion will be evaluated for serviceability in relation to their effect on combustion performance.

Topics covered in this module will include: fuel and air delivery methods to the combustion chamber e.g. port (manifold) injection and direct-injection systems; combustion system design, combustion principles, thermal, mechanical and volumetric efficiency and the stages of combustion; combustion stability, abnormal combustion, air-fuel mixtures, ignition timing and diesel fuel injection timing; evaluation of performance curves from test data; and regulations relevant to the automotive sector and the impact this has on combustion requirements.

On successful completion of this unit, students will be able to interpret engine performance results, evaluate engine design operation, efficiency and serviceability, and discuss the influence that relevant regulations have on combustion.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Investigate the use of engine design features and air–fuel delivery methods to optimise combustion and engine performance

LO2 Explain combustion principles in terms of combustion chemistry and in relation to efficiency variables

LO3 Assess the effect of combustion on performance results and serviceability of combustion related systems

LO4 Discuss regulations and professional standards relevant to combustion engines in the automotive sector.

Essential Content

LO1 Investigate the use of engine design features and air–fuel delivery methods to optimise combustion and engine performance

Engine design features:

Combustion chamber design: pre-chambers, squish and quench areas, spark plug and glow plug location; piston design, port design, bore, stroke

Valve design: location, size, area, valve guides, valve faces, valve seats, curtain area, variable valve timing and lift mechanisms and operation
Cylinder deactivation

Charge motion within the cylinder: tumble and swirl

Camshafts

Engine type and configuration: inline, vee, flat, opposed; overhead cam (OHC); single and multi-cylinder engines; engine location (front, mid, rear)

Compression ratio.

Air–fuel delivery methods:

Port injection: multi-point, sequential injection, continuous injection, pulse width modulation

Manifold design: runner length for optimised performance, plenum design.

Direct injection, spark ignition (SI) and compression ignition (CI) variations, injector position, injector spray pattern, multiple injections per stroke strategies, stratified charge, homogeneous charge compression ignition (HCCI), high pressure common rail systems

Air filtration methods, air intake location

Forced induction: turbo charging, supercharging, intercoolers, anti-lag.

LO2 Explain combustion principles in terms of combustion chemistry and in relation to efficiency variables

Combustion chemistry:

Hydrocarbon fuel composition

Products of combustion for stoichiometric, rich and lean conditions

Balanced combustion reactions in terms of conservation of mass

Energy content of various fuels

Fuel properties: octane rating, cetane rating, volatility, flash point, additives.

Air–fuel mixtures, SI engine ignition timing and CI engine fuel timing:

Air-fuel ratios (AFR), lambda values, equivalence ratios (SI and CI engines)

Ignition timing for various operating conditions and performance outcomes (SI engines)

Fuel timing and sequencing (CI engines).

Combustion-emissions related systems:

Exhaust gas recirculation (EGR), secondary air injection (SAI), positive crankcase ventilation (PCV) systems.

Stages of combustion:

Flame development, rapid burning, flame termination (SI engines)

Flame development, rapid burning, mechanically/electronically controlled phase, flame termination (CI engines)

Introduction to mass fraction burn (MFB): combustion linking to MFB development (1–5% MFB), rapid burning (10–90% MFB)

Burn velocity relating to air–fuel mixture and links to thermal efficiency

Combustion duration relating to spark timing (SI engines) to achieve max. brake torque (MBT) timing.

Combustion stability and abnormal combustion:

Knock, pre-ignition, detonation

Combustion instability caused by compression ratio, rich and lean mixtures.

Combustion efficiency variables:

Application of core engineering principles (i.e. mathematics, science, mechanical and electrical and electronic) suitably in performing calculations: mechanical efficiency, volumetric efficiency, thermal efficiency.

LO3 **Assess the effect of combustion on performance results and serviceability of combustion related systems**

Combustion system performance calculations:

Indicated mean effective pressure (IMEP), brake mean effective pressure (BMEP), frictional mean effective pressure (FMEP)

Calculations from idealised and real engine cycles.

Evaluation of performance results:

Power, torque, thermal efficiency, mean effective pressure (MEP), specific fuel consumption.

Assessment of combustion related system components and serviceability:

Components: cylinder bore/ liner, cylinder head, cylinder head gasket, valve, valve spring, valve guide, valve face, camshaft, camshaft follower, journal, piston, piston ring, conrod, bearing, spark plug

Serviceability tools and equipment: cylinder leakage gauge, compression gauge, straight edge, feeler blade, plastic-gauge, DTI-gauge, micrometer, v-blocks

Serviceability tests: wear, clearance, performance, component condition

Contextual application of relevant occupational knowledge and skills: problem-solving tools and techniques e.g. practical problem solving (PPS) and root cause analysis (RCA)

Maintenance and engineering strategies, practices and techniques: planned, preventative, predictive and reactive; compliance with health and safety regulations and procedures; safe systems of work during inspection/ assessment activities.

LO4 **Discuss regulations and professional standards relevant to combustion engines in the automotive sector**

Regulations relating to combustion:

Global emissions standards development and current sector regulations

Fuel standards.

International standards:

DIN, SAE, ISO, ASTM.

Contextual application of occupational standards and professional duties:

Awareness of engineering international, national and regulatory standards, relevance to the occupation and technician's responsibilities

British Standards (BS); International Organisation for Standardisation standards (ISO); European Norm (EN); follow manufacturers' instructions and standard maintenance procedures for diagnosis and repair; use of test plans and conducting repairs within legal requirements

Occupational standards and job roles: local and global sector needs

Technical report writing and presenting technical information to own teams or target audiences: communicate using the appropriate method for the audience e.g. formal and informal presentations, written reports, verbal, electronic, social media and incorporating relevant and appropriate data or metrics

Professional standards for engineers and technicians (e.g. Institution of Mechanical Engineers (IMechE), Institution of Engineering and Technology (IET), The Indian National Academy of Engineering (INAE), American Society of Mechanical Engineers (ASME))

Ethical behaviour, adherence to best practices and expected competencies.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the use of engine design features and air-fuel delivery methods to optimise combustion and engine performance		**LO1 and LO2**
P1 Investigate key engine design features that influence combustion. **P2** Explain the engine design considerations when using forced induction.	**M1** Discuss how different air–fuel delivery methods influence combustion.	**D1** Analyse a specific vehicle engine design in terms of its combustion performance and efficiencies.
LO2 Explain combustion principles in terms of combustion chemistry and in relation to efficiency variables		
P3 Explain combustion abnormalities and methods to reduce them. **P4** Discuss the benefits and limitations of lean mixture combustion.	**M2** Evaluate combustion composition and air–fuel ratio through the balancing of chemical equations for stoichiometric mixtures.	

Pass	Merit	Distinction
LO3 Assess the effect of combustion on performance results and serviceability of combustion related systems		**LO3 and LO4**
P5 Assess the effect combustion has on key performance results. **P6** Conduct a systematic test procedure on a combustion influencing engine mechanical system for serviceability with records of results.	**M3** Explain characteristics of engine performance graphs, including power, torque, specific fuel consumption, and mean effective pressure, with recommendations of how to improve results.	**D2** Present findings of a systematic test procedure on a combustion influencing engine mechanical system in respect of serviceability and impact on combustion performance.
LO4 Discuss regulations and professional standards relevant to combustion engines in the automotive sector		
P7 Discuss the professional standards expected in the automotive sector, how these may be breached and the impact this could have. **P8** Describe trends in global emissions standards and their influence on combustion.	**M5** Evaluate the role of fuel standards in terms of their impact on combustion, environment and engine performance.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Banish, G. (2007) *Engine Management: Advanced Tuning*. United States: CarTech.

Bell, A. (2006) *Four-Stroke Performance Tuning*. Haynes.

Bell, A. (2002) *Forced Induction Tuning*. Haynes.

Bosch, R. (2022) *Automotive Handbook*. Germany: Wiley.

Burgess, P. and Gollan, D. (2015) *How to Build, Modify and Power Tune Cylinder Heads*. United Kingdom: Veloce Publishing.

Denton T. and Pells H. (2023) *Automobile Mechanical and Electrical Systems.* 3rd Ed. Abingdon: Routledge.

Ferrari G., Onorati, A. and D'Errico, G. (2022*) Internal Combustion Engines.* Italy: Società Editrice Esculapio.

Heywood, J. (2018*) Internal Combustion Engine Fundamentals.* 2nd Ed. USA: McGraw Hill.

(2021) *Internal Combustion Engine Technology and Applications of Biodiesel Fuel*. United Kingdom: IntechOpen.

Pulkrabek, W. (2014) *Engineering Fundamentals of the Internal Combustion Engine*. 2nd Ed. Pearson Education.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Chłopek, Z. et al. (2019) 'Correlational analysis of pollutant emission intensity in various conditions of operation of the automotive internal combustion engine', *Transport* (16484142), 34(4), pp. 490–498. doi:10.3846/transport.2019.11294.

Evans, R.L. (2006) 'Increasing the efficiency of lean-burn automotive engines', *International Journal of Environmental Studies*, 63(4), pp. 441–452. Available at: https://doi:10.1080/00207230600802072.

Yousif, O.M. and Mashkour, M.A. (2024) 'Effects of nozzle diameter and holes number on the performance and emissions of a gasoline direct injection engine', *International Journal of Thermodynamics*, 27(1), pp. 1–12. Available at: https://doi:10.5541/ijot.1272871.

Zhao, X. et al. (2024) 'Experimental study of the performance of turbo-charged gasoline direct-injection engine based on different pre-chamber structures', *Energies* (19961073), 17(7), p. 1773. Available at: https://doi:10.3390/en17071773.

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Transfer

Unit 4035: Welding Technology

Unit 4112: Vehicle Repair and Diagnostics

Unit 4114: Motorcycle Engineering

Unit 4091: Automotive Fundamentals

Unit 5062: Engine and Vehicle Design Performance

Unit 4096: Automotive Workshop Practices

Unit Code: D/651/3049

Level: 4

Credits: 15

Introduction

Safety takes centre stage in the dynamic world of automotive engineering. It is essential to foster a strong culture of safety and responsibility in the automotive workshop environment, with a focus on protecting personnel, the environment and the wider community. From health and safety protocols to environmental sustainability practices, and from hybrid and electric vehicle safety to hazardous waste disposal, this unit enables students to comprehensively explore the essential practices and procedures necessary to maintain a safe and secure workshop environment.

In this unit, the student will delve into the importance of health and safety in the automotive workshop, emphasising the need for rigorous safety standards and protocols to prevent accidents, injuries and environmental harm. Throughout the unit, students will gain a deep understanding of health and safety regulations, guidelines and best practices applicable to automotive workshops, covering topics such as risk assessment, hazard identification, emergency response procedures and the use of personal protective equipment. Additionally, students will explore the unique safety considerations associated with hybrid and electric vehicles, including high-voltage systems, battery handling and safe maintenance practices.

Key issues addressed include the importance of environmental sustainability in automotive workshop operations, the responsible disposal of hazardous waste, recycling initiatives and pollution prevention strategies. Students will learn about the environmental impact of automotive activities and the role of workshops in minimising their ecological footprint through responsible waste management and sustainable practices.

By the end of this unit, students will have acquired a comprehensive understanding of automotive workshop practices, as well as the practical skills and knowledge necessary to ensure the safety of personnel, protect the environment and comply with regulatory requirements to enable them to work in various workplace contexts such as vehicle manufacturers factory, dealership, an independent garage or a research facility.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Implement effective health and safety protocols and practices in the workshop

LO2 Apply safety protocols and procedures specific to hybrid and electric vehicles

LO3 Discuss the environmental impact of automotive workshop activities

LO4 Determine relevant regulatory requirements and standards governing local automotive workshop operations.

Essential Content

LO1 **Implement effective health and safety protocols and practices in the workshop**

Safety first culture:

Local workshop context, layout, documentation, checklists and dos and don’ts

Regulations, policies, procedures and practices, compliance, quality safety systems of work, good practice.

Personal protective equipment (PPE):

Range, correct and incorrect use of PPE: implications; what should be employer or employee provided

Regular monitoring of PPE condition

Appropriate PPE for various work practices

Safety issues relating to working on automotive vehicles and incorrect use of PPE

Hazard and safety priorities when working on automotive vehicles.

Tools and equipment:

Tools and equipment including electric machines used in an automotive workplace

Safe and correct handling and use of all tools and equipment

Training on use of certain tools.

Risk assessments:

Use of risk assessments

Creating and updating risk assessments

Assessing dangers, occupational hazards and potential accidents within an automotive workplace; prevention

Appropriate signage, PPE and updates to workshop practices to mitigate and minimise risks.

LO2 **Apply safety protocols and procedures specific to hybrid and electric vehicles**

Safety in hybrid and electric vehicles:

Hazard and safety priorities, a range of safety issues relating to electric and hybrid vehicles

Protection of personnel, prevention of accidents and injuries, and safe maintenance practices

Appropriate tools for working with high-voltage systems

Legislation and standard operating procedures (SOPs) associated with hybrid and electric vehicles

Risks of working with electric and hybrid vehicles.

Low- and high-voltage systems:

Difference between low voltage, medium voltage and high voltage

Protection methods and risks

Isolation and de-energising.

Battery health and safety:

Electrolyte safety

Failures and hazards

Fire safety

Health and safety legislation

Spillage.

LO3 **Discuss the environmental impact of automotive workshop activities**

Automotive industry environmental considerations:

Climate change

Air pollution

Sustainability and sustainable practices

Vehicle emission standards and drive cycles

Environmental impact the automotive industry creates, including cradle-to-grave considerations.

Disposal of hazardous waste:

Minimise generation of hazardous waste

Ethical disposal and recycling

Control of substances hazardous to health (COSHH)

Appropriate extraction systems within an automotive workplace

Suitable protocols to minimise ecological footprints.

LO4 **Determine relevant regulatory requirements and standards governing local automotive workshop operations**

Industry standards and regulations:

ATEX and DSEAR

ISO standards

Road safety regulations (e.g. UK or appropriate country regulations)

Industry guidelines

Region-specific regulations: for example –

The Road Vehicles (Approval) Regulations 2009

The Road Vehicles (Construction and Use) Regulations 1986

The Environmental Protection Act 1990

The Health and Safety at Work Act 1974.

Automotive workshop job roles:

Examples of local job roles, global careers

Professional competencies and behaviours, CPD

Trends and challenges.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Implement effective health and safety protocols and practices in the workshop</td><td rowspan="4">LO1 and LO2

D1 Produce a risk assessment for the workshop environment, selecting suitable control measures, prior to undertaking working on a hybrid or electric vehicle.</td></tr>
<tr><td>P1 Propose appropriate personal protective equipment that should be supplied by an employer and employee.

P2 Implement safe working practices for typical hand tools and machines used in the automotive industry.</td><td>M1 Assess typical accidents and injuries that may occur when working on motor vehicles or when using tools and equipment.</td></tr>
<tr><td colspan="2">LO2 Apply safety protocols and procedures specific to hybrid and electric vehicles</td></tr>
<tr><td>P3 Recommend appropriate personal protective equipment for safe working on hybrid and electric vehicles.

P4 Apply safe working practices while using tools for hybrid and electric vehicles.</td><td>M2 Evaluate typical accidents and injuries that may occur when working on hybrid and electric motor vehicles.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Discuss the environmental impact of automotive workshop activities		**LO3 and LO4**
P5 Discuss hazardous waste legislation appropriate to the automotive industry in a local context. **P6** Describe safe disposal practices of hazardous waste in a local context.	**M3** Explain how appropriate waste disposal aids in minimising the automotive industries ecological footprint.	**D2** Analyse trends in regulatory standards and adherence to legislation to ensure a balanced ecological footprint.
LO4 Determine relevant regulatory requirements and standards governing local automotive workshop operations		
P7 Determine appropriate health and safety regulatory requirements in the local workplace or a given setting. **P8** Apply appropriate waste and environmental policies within the workplace or a given setting.	**M4** Examine professional competences and how they apply to global careers.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Denton, T. (2020) *Electric and Hybrid Vehicles,* 2nd Ed. Oxon: Routledge.

Husain, I. (2021) *Electric and Hybrid Vehicles: Design Fundamentals*. 3rd Ed. Oxon: CRC Press.

Pistoia, G. and Liaw, B. (2018) *Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost (Green Energy and Technology)*. Switzerland: Springer.

Quarto, M. and Goodnight, N. (2022) *Light Duty Hybrid and Electric Vehicles (Master Automotive Technician)*. Massachusetts: Jones & Bartlett Publishers.

Schramm, D. and Hesse, B. (2020) *Vehicle Technology: Technical foundations of current and future motor vehicles.* Berlin: De Gruyter Oldenbourg.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

D'amore, L., Costa, D. and Messagie, M. (2024) 'Economic and environmental assessment of technologies optimizing the execution of long trips for electric vehicles', *World Electric Vehicle Journal*, 15, pp. 128. Available at: https://doi.org/10.3390/wevj15040128.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4097: Electric Vehicle Battery Manufacture

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 4097: Electric Vehicle Battery Manufacture

Unit Code: J/651/3050

Level: 4

Credits: 15

Introduction

The future of the automotive industry is increasingly focused on electric vehicles and the development of sustainable battery technology. The transition from conventional to electric vehicle battery manufacture marks a significant shift in production methods, driven by advancements in materials science and automation. Major players such as Tesla, Panasonic and LG Chem are pioneering these changes, investing heavily in research and development to enhance battery efficiency, longevity and environmental impact. Industry needs are evolving, with a growing demand for engineers skilled in battery technology, safety practices and legislative compliance. As safety practices evolve, it is crucial that engineers are well versed in legislation affecting current battery manufacturing facilities and, ultimately, the future of automotive manufacturing. This sector offers diverse job roles, from materials scientists and process engineers to quality control specialists and sustainability managers, all contributing to the innovation and efficiency of electric vehicle battery production.

The aim of this unit is to deepen understanding of both current and emerging technologies, focusing on safe operations within the battery manufacturing sector.

Among the topics taught in this unit are: legislation, responsibilities, and health and safety regulations surrounding battery technology; safe working environments; the industry's impact on the environment and how the development of new technologies is driven by sustainability; fundamentals of battery technology, including its architecture and chemical composition; and the process of developing and manufacturing modern high-voltage batteries.

Upon successful completion of this unit, students will attain theoretical and technical knowledge of current manufacturing techniques and battery technology, along with appropriate health and safety practices in the electric automotive industry. They will be equipped to analyse, interpret and evaluate relevant information, recognising the environmental impacts and sustainability requirements that must be considered in the manufacture of electric vehicle batteries.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Explore health and safety regulations, protocols and personnel responsibilities, and industrial legislation with respect to hybrid and electric vehicle battery technology

LO2 Discuss the impact on the environment and viability of a sustainable future with hybrid electric vehicles and current automotive applications

LO3 Explore the fundamentals of battery technology and design for electric vehicle applications

LO4 Evaluate the battery manufacturing process and safe working practices.

Essential Content

LO1 Explore health and safety regulations, protocols and personnel responsibilities, and industrial legislation with respect to hybrid and electric vehicle battery technology

Health and safety for battery manufacture:

Accident reporting and investigation

Regulations – atmospheres explosible (ATEX) and dangerous substances and explosive atmospheres regulations (DSEAR)

Control of substances hazardous to health (COSHH)

Control of major accident hazards regulations (COMAH)

Electrolyte safety

Failures and hazards

Fire safety

Health and safety legislation, protocols with respect to hybrid vehicles and electric vehicles

Manual handling

NMP (N-Methlpyrrolidone)

Spillage

Personnel: responsibilities, training, reskilling/upskilling.

LO2 Discuss the impact on the environment and viability of a sustainable future with hybrid electric vehicles and current automotive applications

Environmental considerations for battery manufacture:

Climate change

Greenhouse gases, global warming, air pollution

Sustainability

Environmental impact in battery manufacturing

Social considerations in battery manufacturing

Economic considerations in battery manufacturing

Overall environmental impact in automotive applications; viability of sustainable future with hybrid and electric vehicles

Full life cycle assessment to include financial and social aspects

Toolsets to measure environmental impact.

Sustainability for battery manufacture:

Net zero

Carbon footprint

Environmental offsetting

Sustainability; cradle to the grave life cycles, life cycle assessment

Sourcing of precious metals and lithium mining

Ethical issues

Recycling, disposing, decommissioning and re-utilisation of batteries

Three pillars of sustainability

Tools to measure sustainability

Sustainability considerations for battery manufacturing

Driving sustainability in manufacturing.

LO3 **Explore the fundamentals of battery technology and design for electric vehicle applications**

Electric vehicle battery fundamentals:

Battery fundamentals: terminology, layout and construction

Key materials

Energy versus power

Cost and lifecycle

Cells*:* dry and wet cell

Cell configuration

Cell chemistries*:* current and future*,* for example, lead–acid (Pb), nickel cadmium (NiCd), nickel metal hydride (NiMH), *lithium-ion*, *s*odium-ion, *s*olid state

Battery management systems.

LO4 **Evaluate the battery manufacturing process and safe working practices**

Battery manufacturing for automotive electric vehicles:

Fundamentals of battery supply chain systems

Battery manufacturing overview

Battery manufacturing process: electrode, cell assembly, formation, ageing and testing, module and pack and finishing

Process equipment overview

Manufacturing process: mixing, coating and drying, calendering and slitting

Cylinder/pouch assembly

Formation, age and test

Module assembly, pack assembly

Clean and dry rooms in battery manufacturing: main constituents of a clean and dry room, components of the clean and dry room conditioning system

Entry protocols and procedures, air shower, PPE, prohibited materials, emergencies.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore health and safety regulations, protocols and personnel responsibilities, and industrial legislation with respect to hybrid and electric vehicle battery technology		
P1 Differentiate between near misses, incidents, and accidents in situations that may lead to an accident. **P2** Determine the application of control measures and the employer's responsibilities. **P3** Explore potential battery hazards and failures during the manufacturing process.	**M1** Describe the structure of the law, including acts, regulations, standards, and codes of practice that apply to working on or around lithium-ion batteries.	**D1** Determine the duties and responsibilities of the employer and employee in creating risk assessments for typical industry scenarios with regards to electric vehicle battery handling and manufacture.
LO2 Discuss the impact on the environment and viability of a sustainable future with hybrid electric vehicles and current automotive applications		
P4 Discuss the sources and harmful effects of vehicle air pollution and implications of current and future regional vehicle CO_2 emissions reduction targets. **P5** Investigate the key features of climate policies and global and regional climate change legislation and emission reduction. **P6** Analyse the environmental benefits of batteries in energy innovation.	**M2** Propose sustainable development measures to mitigate global climate change. **M3** Examine strategies to improve sustainability in battery manufacturing.	**D2** Critically analyse sustainability and its applications in the battery manufacturing industry.

Pass	Merit	Distinction
LO3 Explore the fundamentals of battery technology and design for electric vehicle applications		
P7 Explore the function and construction of a battery and key materials used in electric vehicle battery manufacturing. **P8** Discuss battery classifications and the advantages and disadvantages of different battery types. **P9** Determine appropriate applications for dry cell and wet cells.	**M4** Determine key battery specifications with regards to energy and power, and specifications for electric vehicle applications. **M5** Discuss the advantages and disadvantage of different cell chemistries.	**D3** Evaluate charging and discharging operations and architecture of a battery management system.
LO4 Evaluate the battery manufacturing process and safe working practices		
P10 Investigate the current key processes of making a lithium-ion battery. **P11** Investigate correct implementation of safe working practices in the battery manufacture process. **P12** Evaluate the requirements for clean and dry rooms in battery manufacturing.	**M6** Discuss prescribed processes and protocols for entering, working in and exiting clean and dry rooms in battery manufacturing.	**D4** Analyse potential injuries and incidents that could occur during the battery manufacturing process and industry-wide accident mitigation strategies.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Badawy, W. and Jullien, G.A. (2021) *Automotive Cybersecurity: Engineering Challenges for Connected and Automated Vehicles.* Cham: Springer.

Denton, T. (2020) *Electric and Hybrid Vehicles,* 2nd Ed. Oxon: Routledge.

Ehsani, M., Gao, Y., Longo, S. and Ebrahimi, K. (2021) *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design.* 4th Ed. Boca Raton, FL: CRC Press.

Husain, I. (2021) *Electric and Hybrid Vehicles: Design Fundamentals*. 3rd Ed. Oxon: CRC Press.

Nah, K.-D. (2021) *Automotive HVAC: Energy Management in Electric and Plug-in Hybrid Vehicles.* New York: Springer.

Pistoia, G. and Liaw, B. (2018) *Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost (Green Energy and Technology)*. Switzerland: Springer.

Pistoia, G., Liaw, B. and Kang, J. (2021) *Battery Technology and Applications.* 3rd Ed. Amsterdam: Elsevier.

Quarto, M. and Goodnight, N. (2022), *Light Duty Hybrid and Electric Vehicles (Master Automotive Technician)*. Massachusetts: Jones & Bartlett Publishers.

Scrosati, B., Garche, J. and Tillmetz, W. (2021) *Advances in Battery Technologies for Electric Vehicles.* 2nd Ed. Cambridge: Woodhead Publishing.

eBooks

Pistoia G. (2010) *Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market*. Available at:

https://www.perlego.com/book/1836150/electric-and-hybrid-vehicles-power-sources-models-sustainability-infrastructure-and-the-market-pdf?utm_source=google&utm_medium=cpc&campaignid=15781033413&adgroupid=134828831507&gclid=CjwKCAiAuOieBhAIEiwAgjCvcuCu3XRkum0sntnT1G9gkQ8nw3QlHuOirnReSYl3KL0xd26w6avHTBoClxMQAvD_BwE

Journals and articles

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Beaudet, A., Larouche, F., Amouzegar, K., Bouchard, P. and Zaghib, K. (2020) 'Key challenges and opportunities for recycling electric vehicle battery materials', *Sustainability*, 12, pp. 5837.

Sanguesa, J.A., Torres-Sanz, V., Garrido, P., Martinez, F.J. and Marquez-Barja J.M. (2021) 'A review on electric vehicles: Technologies and challenges', *Smart Cities,* 4, pp. 372–404.

Shao-Chao, M., Jin-Hua, X. and Ying, F. (2022) 'Characteristics and key trends of global electric vehicle technology development: A multi-method patent analysis', *Journal of Cleaner Production,* 338.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 5063: Further Hybrid and Electric vehicle Technologies

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit Code: K/651/3051

Level: 4

Credits: 15

Introduction

Hybrid and electric vehicle technologies are revolutionising the automotive industry, driven by the urgent need for sustainable transportation solutions. As concerns about environmental impact and fossil fuel dependency intensify, these technologies are becoming increasingly important. Recent advancements in battery efficiency, charging infrastructure and vehicle range are accelerating the adoption of electric and hybrid vehicles globally. However, this shift also highlights significant skill gaps, necessitating new roles such as battery management specialists, EV system designers and sustainable mobility consultants. Industry and academia are now focused on developing training programmes and educational pathways to equip a new generation of engineers and technicians with the skills needed to advance this revolution.

The aim of this unit is to provide an understanding of current and emerging technologies, their deployment, and safe practices with high-voltage systems when working with hybrid and electric vehicle systems.

Topics covered in this unit include: legislation, responsibilities and health and safety regulations surrounding high-voltage vehicle systems; hybrid and electric vehicle architecture, charging technologies, system requirements, designing hybrid and electric vehicle systems; and diagnostic and rectification techniques associated with high and low voltage systems.

Upon successful completion of this unit, students will attain practical, theoretical, and technical knowledge of trends in the hybrid and electric automotive Industry. They will be equipped to analyse, interpret, and evaluate information to design prototype systems and adeptly handle diagnostics and problem rectification, ensuring compliance with health and safety standards.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Explore hybrid and electric vehicle technologies, trends, industry requirements and compliance

LO1 Assess the architectural features of hybrid and electric vehicles against the key principles and technological requirements

LO1 Evaluate the design developed for a hybrid or electric vehicle prototype system through implementation of established engineering practices

LO1 Rectify a hybrid or electric vehicle system fault or failure as a follow up to the diagnosis using industry methods and equipment.

Essential Content

LO1 **Explore hybrid and electric vehicle technologies, trends, industry requirements and compliance**

Automotive hybrid and electric vehicles:

Hybrid and electric vehicles: trends, technologies, industry requirements, strategy and vision; terminology and local variations

Hazard and safety priorities; type of work (from awareness to live work)

Safety issues relating to electric and hybrid vehicles

Difference and impact – low voltage and high voltage

AC and DC effect on current

Electrical current and cabling thickness*: relevant to the context*

Quality control and assurance of electrical systems

Legislation including ISO26262 safety standards.

Standard operating procedures (SOPs) related to working safely on hybrid/electric vehicles.

Isolation/lockout and re-energising of automotive hybrid and electric vehicles:

Battery isolation

Protection methods

Chargers (e.g. on-board, external) and charging safety methodology

Connecting the battery modules

Isolation and de-energising.

LO2 **Assess the architectural features of hybrid and electric vehicles against the key principles and technological requirements**

Electrical engineering principles and automotive applications:

Electrical power

Ohm's law, Kirchoff's law and electron theory

Electrical components (e.g. inverter components, fuses and busbars in a battery pack)

Three-phase systems

Applications in automotive engineering and specifically hybrid and electric vehicles.

Electric and hybrid vehicles:

Types of electric/hybrid vehicles

BEV and HEV components

Parameter design for performance

Automotive and high-voltage connectors

Battery, motor and inverter cooling

Control technology for battery, SOC and motor deployment.

Hybrid and electric vehicle battery technologies:

Vehicle batteries*:* industry terminology

Lithium and nickel battery chemistry fundamentals and cell construction

Battery layout(s)

Battery management system: on-board charging, basic slow charging, slow, fast and rapid charging

Inductive charging.

LO3 **Evaluate the design developed for a hybrid or electric vehicle prototype system through implementation of established engineering practices**

Engineering design methodologies for hybrid and electric vehicles:

Prototyping, stakeholders' requirements and roles

Non-disclosure agreements (NDA's)

Patents

Prototyping methodologies, system vs engineering

Test and development

Validation.

Electric simulation and virtual prototype builds:

Hardware-in-the-loop (HIL) simulation

Structural construction

Motor and drive train components

Vehicle battery box construction

Noise vibration and harshness

Project/kit builds, use of donor vehicle(s)

Chassis, ride and handling

Benchmarking and real-world testing.

Managing electric vehicle prototype builds:

Milestones phasing

Planning and execution: scheduling, Gantt charts

Failure mode and effects analysis (FMEA)

Process optimisation

Risk management.

LO4 **Rectify a hybrid or electric vehicle system fault or failure as a follow up to the diagnosis using industry methods and equipment**

Diagnostics in automotive electric vehicle systems and batteries:

Wiring diagrams and test equipment

Fault finding in electric and hybrid vehicles

Problem-solving process

Approaching fault diagnosis

Battery problem

Charging problems

Diagnostics interrogation.

Repairs, rework and high-voltage component replacement on automotive electric vehicles:

PCB rework including soldering

Electronic component repair and replacement

Common problems associated with hybrid and electric vehicles

Fast charging leads and sockets

Rapid charging lead and socket

Battery HV connection, battery junction box

Cooling systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore hybrid and electric vehicle technologies, trends, industry requirements and compliance		**LO1 and LO2**
P1 Explore safe working workshop practices around electric and hybrid vehicles. **P2** Determine how to comply with the statutory regulations and organisational safety requirements for vehicles with electric drive systems or energy storage devices.	**M1** Analyse compliance with statutory regulations and organisational safety requirements for vehicles with electric drive systems or energy storage devices in the workplace or a given setting.	**D1** Interpret manufacturer SOPs (standard operating procedures) in the architectural aspects of high-voltage component assembly to ensure compliance with relevant safety and legislative requirements.
LO2 Assess the architectural features of hybrid and electric vehicles against the key principles and technological requirements		
P3 Assess typical hybrid and electric vehicle layouts and architecture. **P4** Demonstrate the ability to use engineering mathematics on electrical systems and circuits in relation to high-voltage automotive vehicle architecture. **P5** Apply a range of electrical laws in relation to high-voltage automotive vehicle architecture.	**M2** Illustrate architectural components and technological requirements for a typical hybrid and electric vehicle system.	

Pass	Merit	Distinction
LO3 Evaluate the design developed for an hybrid or electric vehicle prototype system through implementation of established engineering practices		
P6 Review how to structure electric vehicle prototype build(s) in line with organisation procedures. **P7** Evaluate virtual build processes to validate the assembly process for electric vehicles.	**M3** Determine resource allocation for prototyping electric vehicles and suitable processes and timelines to complete prototype assembly.	**D2** Design a test strategy and a test plan to showcase deliverables required when bringing a prototype to market.
LO4 Rectify a hybrid or electric vehicle system fault or failure as a follow up to the diagnosis using industry methods and equipment		
P8 Rectify errors/faults in vehicle power/ battery systems using high-voltage diagnostic tools. **P9** Demonstrate awareness of the characteristics of power electronics, installation, cooling, interface, connection, grounding and handling requirements. **P10** Demonstrate working safely on an electric/hybrid vehicle.	**M4** Implement diagnostics in a controlled environment to gauge whether a system or component meets the required criteria and resolve faults. **M5** Carry out repairs on high energy electrical systems correctly.	**D3** Apply required safety protocols when assembling high-voltage components into a high-voltage system. **D4** Report relevant information detailing repairs in line with industry processes.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Denton, T. (2020) *Electric and Hybrid Vehicles*. 2nd Ed. Oxon: Routledge.

Ehsani, M., Gao Y. and Emadi, A. (2018) *Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals, Theory, and Design.* 3rd Ed. Boca Raton, FL: CRC Press.

Emadi, A. (2019) *Advanced Electric Drive Vehicles.* Boca Raton, FL: CRC Press.

Husain, I. (2021) *Electric and Hybrid Vehicles: Design Fundamentals,* 3rd Ed. Oxon: CRC Press.

Larminie, J. and Lowry, J. (2012) *Electric Vehicle Technology Explained.* 2nd Ed. Chichester: Wiley.

Quarto, M. and Goodnight, N. (2022) *Light Duty Hybrid and Electric Vehicles (Master Automotive Technician)*. Massachusetts: Jones & Bartlett Publishers.

eBooks

Mavropoulos, G., Andritsakis, E.C. and Papagiannakis, R.G. (2023) *Internal Combustion Engine Performance. Special Issue of Energies.* Available at: https://www.mdpi.com/journal/energies/special_issues/Internal_Combustion_Engine_Performance_2023.

Pistoia, G. (2010) Electric and Hybrid Vehicles Power Sources, Models, Sustainability, Infrastructure and the Market. Available at:

https://www.perlego.com/book/1836150/electric-and-hybrid-vehicles-power-sources-models-sustainability-infrastructure-and-the-market-pdf?utm_source=google&utm_medium=cpc&campaignid=15781033413&adgroupid=134828831507&gclid=CjwKCAiAuOieBhAIEiwAgjCvcuCu3XRkum0sntnT1G9gkQ8nw3QlHuOirnReSYl3KL0xd26w6avHTBoClxMQAvD_BwE

Journals and articles

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Sanguesa, J.A., Torres-Sanz, V. Garrido, P. Martinez, F.J. and Marquez-Barja, J.M. (2021) 'A review on electric vehicles: Technologies and challenges', *Smart Cities*, 4, pp. 372–404.

Shao-Chao, M. Jin-Hua, X. and Ying F. (2022) 'Characteristics and key trends of global electric vehicle technology development: A multi-method patent analysis', *Journal of Cleaner Production,* 338.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4097: Electric Vehicle Battery Manufacture

Unit 5063: Further Hybrid and Electric vehicle Technologies

Unit 4099: Industrial Digitalisation Technologies for Engineers

Unit Code: L/651/3052

Level: 4

Credits: 15

Introduction

The engineering industry is undergoing a rapid transformation driven by the necessity to keep pace with technological advancements. Industrial digitalisation technologies (IDT) have become a cornerstone for businesses within the sector, emphasising the importance of staying competitive and efficient through advanced engineering techniques. The advent of Industry 4.0, often referred to as the 'fourth industrial revolution', is marked by the integration of cyber-physical systems with the Internet of Things (IoT) and services. This revolution is characterised by the fusion of high-performance computing, the internet and the development of advanced manufacturing technologies, setting a new standard in industrial innovation. The proliferation of IDT not only revolutionises production and manufacturing processes but also opens up a plethora of new career opportunities and roles. Graduates can look forward to roles such as systems analysts, industrial data scientists, digital transformation consultants and smart factory managers, all of which require a new set of skills tailored to the digital age.

The aim of this unit is to provide students with a comprehensive understanding of industrial digitalisation technologies and their application across various domains including research and development, initial concept design and industrial manufacturing. The objective is to illuminate the pivotal role that advancements in computing and engineering systems play in transforming the engineering industry, enhancing design and development processes, boosting manufacturing efficiency, and broadening accessibility for future engineers.

The unit covers a broad spectrum of topics central to industrial digitalisation technologies. Initially, students will delve into the historical factors and consequences of industrial revolutions with a special emphasis on Industry 4.0. The exploration continues with an extensive review of the technologies that enable smart engineering and manufacturing. Subsequent topics include the latest advancements in software, hardware and artificial intelligence that support the design and execution of engineering products and processes. The unit also highlights how a deeper human understanding of systems engineering has led to significant enhancements in the integration of software and computer interfaces, which, in turn, facilitates a more effective interaction between engineers and their design targets.

On successful completion of this unit, students will be capable of critically analysing the evolution and current state of industrial revolutions, in particular, focusing on the transformative impact of industrial digitalisation technologies. As future engineers, managers or department heads, students will assess the strategic shifts towards Industry 4.0, incorporating state-of-the-art computing systems and technologies. They will gain profound insights into impending industry developments and trends. With a solid foundation in both practical and theoretical aspects of IDT, students will confidently tackle well-defined but complex problems, applying their knowledge to innovate and streamline solutions while continually evaluating the effectiveness of their approaches and outcomes.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Investigate IT Infrastructure, networks and Industrial Internet of Things (IIoT) when transitioning to Industry 4.0 and beyond

LO2 Examine emerging technologies in engineering for the transition to smart manufacturing of future industries

LO3 Analyse the operation and application of machine learning and artificial intelligence to enhance engineering problem identification and solution efficiency

LO4 Discuss the role and influence of immersive technologies for developing improved design processes in computer-sided engineering software.

Essential Content

LO1 **Investigate IT infrastructure, networks and Industrial Internet of Things (IIoT) when transitioning to Industry 4.0 and beyond**

Digital infrastructure and data acquisition:

Background, introduction, key components, technology drivers of infrastructure evolution, advancements, and future trends

Collecting, converting and transforming data and legacy data; sharing, exchanging and converting data; preventing asset failure; analysing production data to identify patterns and predict issues.

Networks:

Standards and network protocols

Wired communication networks

Wireless communication networks.

Industrial Internet of Things (IIoT):

Concept of IIoT, use cases

Industry 4.0 concepts, beyond Industry 4.0

Applications of intelligent systems

Commercial value of digitisation and digitalisation.

Career opportunities and job roles:

Job market, competencies to meet local and global job roles (e.g. IT security, supervisor, automation technician, robotics engineer, UX designer, team coach, validation engineer, data scientist, visual engineer, IT director, architect, code and algorithm developer, machine learning engineer and IoT engineer)

Professional roles and duties.

LO2 **Examine emerging technologies in engineering for the transition to smart manufacturing of future industries**

Digital twinning for the manufacturing industry:

Introduction to digital twins, historical pre-digital twins

Categorisation of digital twins

Architecture, structure and functions of digital twins

Digital twin requirements, implementation and interactions with physical assets.

Software and tools for virtual engineering:

Concepts and models: computer-aided engineering (CAE), computer-aided design (CAD), computer-aided manufacturing (CAM), case studies and work scenarios

Types of simulation tools: CAE and CAD simulation tools e.g. computer-aided design (CAD), finite element method (FEM), computational fluid dynamics (CFD), structural optimisation

Optimisation tools: discrete event simulation (DES), agent-based modelling (ABM), simulation optimisation

Coordinate measuring machine (CMM), computer numerical control (CNC), G-code.

Digital tools and techniques for supply chain management:

Introduction, examples of supply chain management, differences between traditional and digital supply chain networks

Examples of supply chain structures and problems

Digitalisation of the supply chain

Supply chain modelling: data and information requirements, supply chain risks, software tools and supply chain optimisation.

LO3 **Analyse the operation and application of machine learning and artificial intelligence to enhance engineering problem identification and solution efficiency**

Practical data analysis:

Role of data analytics in Industry 4.0: processes, tools and types of data analytics

Data science, data modelling, data management

Data protection protocols

Data ethics, regulation, data protection, tools and techniques, data protection implications.

Machine learning in manufacturing:

Concepts and principles of machine learning, machine learning in Industry 4.0

Differences between supervised and unsupervised learning

Machine learning algorithms: tools, problems and limitations.

Deep learning and artificial intelligence:

Introduction to deep learning and artificial intelligence technologies

Types and classification of artificial intelligence: assisted intelligence, augmented intelligence, autonomous intelligence and automated intelligence, artificial narrow intelligence (ANI), artificial general intelligence (AGI) and artificial super intelligence (ASI)

Real-world applications of artificial intelligence: simple and deep neural networks, deep feedforward neural networks, convolutional neural networks (CNN), recurrent neural networks (RNN)

Safety considerations for machine learning and artificial intelligence implementation.

LO4 **Discuss the role and influence of immersive technologies for developing improved design processes in computer-aided engineering software**

Immersive engineering:

Virtual reality: scene capturing, scene processing, scene identification, scene visualisation

Augmented reality: examples, properties, depth of immersion, mixed reality

Virtual reality modelling languages

Differences between mixed, augmented and virtual realities

Considerations of using immersive technology: safety, privacy, security and cost.

Applications of immersive technologies:

Industrial applications of augmented and virtual reality: design, test, maintenance, assembly and training

Implementation of virtual reality and augmented reality technologies

3D visual representations: 3D modelling, 3D visualisation and product rendering, materials and textures, lighting and resolution

3D rendering techniques: real-time (interactive) rendering, multi-pass rendering, non-real-time (offline) pre-rendering and perspective projection

Analysis and design: feedback and refinement.

Human interaction and immersion with digital environments:

The human: senses and capabilities

Conventional and haptic interfaces: visual and auditory information, kinaesthetic, touch.

Force, vibration, motion feedback

Haptics technology: human, machine and computer haptics

Haptic interface and the human hand

Training requirements and acclimatisation to immersive technologies.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate IT Infrastructure, networks and Industrial Internet of Things (IIoT) when transitioning to Industry 4.0 and beyond		**LO1 and LO2**
P1 Describe IT infrastructures and the evolution of key components. **P2** Analyse wired and wireless data communication standards and network protocols. **P3** Investigate two use cases for the Industrial Internet of Things (IIoT) in support of transition.	**M1** Investigate the advantages and disadvantages of artificial technologies for a given engineering scenario necessitating transition.	**D1** Evaluate the organisational impact and change management methods used when transitioning from Industry 3.0 to Industry 4.0.
LO2 Examine emerging technologies in engineering for the transition to smart manufacturing of future industries		
P4 Describe the relevance and necessity for the digital twin methodology in engineering applications. **P5** Examine the use of computer-aided engineering software and tools for engineering processes.	**M2** Analyse the impact of any two emerging technologies on supply chain management.	

Pass	Merit	Distinction
LO3 Analyse the operation and application of machine learning and artificial intelligence to enhance engineering problem identification and solution efficiency		
P5 Review methods of data science involved with practical data analysis and the ethics of data control and security. **P6** Analyse the application of machine learning and artificial intelligence principles	**M3** Utilise machine learning programming as a tool to manipulate a data set for a given application scenario.	**D2** Analyse artificial intelligence and deep-learning techniques for industrial applications.
LO4 Discuss the role and influence of immersive technologies for developing improved design processes in computer-aided engineering software		
P7 Compare the differences of various levels of reality immersion technologies within industrial applications. **P8** Discuss various levels of rendering complexity and its effect on user immersion.	**M4** Discuss the technological requirements for human interaction and immersion with digital environments.	**D3** Analyse human limitations with regards to health or safety when developing new immersive digital technologies.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Almada-Lobo, F. (2020) *Smart Manufacturing: Concepts and Methods*. Springer.

Ayomaya, B.A. (2022) *Digital Infrastructure for Beginners: A beginners guide to understanding the world of Digital Infrastructure*. USA: Independently published.

Butun, I. (2020) *Industrial IoT: Challenges, Design Principles, Applications, and Security*. Springer.

Goodfellow, I., Bengio, Y. and Courville, A. (2020) *Deep Learning*. MIT Press.

Kim, M. J., Lee, K. H., Park, H. W. and Rhee, P. K. (2021) *Immersive Technology in Smart Manufacturing: A Practical Guide to AR and VR for Engineers*. Wiley.

Lee, J., Davari, H., Singh, J. and Pandhare, V. (2020) *Industrial AI: Applications with Sustainable Performance*. Springer.

Misra, S. Roy, C. and Mukherjee, A. (2020) *Introduction to Industrial Internet of Things and Industry 4.0*. Florida: CRC Press.

Nath, S.V. and Van, Schalkwyk P. (2021) *Building Industrial Digital Twins: Design, Develop, and Deploy Digital Twin Solutions for Real-world Industries using Azure Digital Twins.* Birmingham: Packt Publishing.

Rothman, D. (2020) *Artificial Intelligence by Example: Acquire advanced AI, machine learning, and deep learning design skills.* 2nd Ed. Birmingham: Packt Publishing.

Russo, R. (2020) *Data Science for Beginners: 2 Books in 1: Deep Learning for Beginners + Machine Learning with Python – A Crash Course to Go Through the Artificial Intelligence Revolution, Python and Neural Networks*. United Kingdom: Independently published.

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Mahesh, B. (2020) 'Machine learning algorithms – A review', *International Journal of Science and Research*, 9(1), pp. 381–386.

Zheng, T. Ardolino, M. Bacchetti, A. and Perona, M. (2021) 'The applications of Industry 4.0 technologies in manufacturing context: A systematic literature review', *International Journal of Production Research*, 59(6), pp.1922–1954.

Links

This unit links to the following related units:

Unit 4023: Computer-Aided Design and Manufacture (CAD/CAM)

Unit 4035: Welding Technologies

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 4100: Lean Six Sigma for Engineers (leading to Green Belt)

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 5064: Further Industrial Digitalisation Technologies for Engineers

Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt)

Unit 5069: Vehicle Systems and Technology

Unit 4100: Lean Six Sigma for Engineers (leading to Green Belt)

Unit Code: F/651/3068

Level: 4

Credits: 15

Introduction

Engineering is a discipline where opportunities for improvement can be widely found. Such improvements may arise across all aspects of engineering or manufacturing processes and require both a disciplined approach to improvement and knowledge of suitable 'tools' to be used in order to progress any such improvements.

In this unit, students will be introduced to commonly used improvement techniques and to a range of tools to be used during such improvement projects. The unit aims to equip students with the knowledge and skills in using a well-known improvement methodology at a high level of proficiency (i.e. Lean Practitioner Standard ISO18404).

Studying this unit alongside *Unit 4004 Managing a Professional Engineering Project* would enable a student to achieve the Green Belt foundation award subject to submission of a project portfolio. Topics covered include: improvement methodologies such as define, measure, analyse, improve and control (DMAIC); Toyota 8 Step Practical Problem Solving (TPPS); and 8 Disciplines (8D). It will also cover tools to aid improvement such as project charters, voice of the customer, analytical tools, '5 Whys' analysis and other such tools and techniques.

On successful completion of this unit, students will be able to carry out a step-by-step process improvement using a range of improvement tools in order to complete an improvement project to improve a business metric arising from the engineering/manufacturing processes.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Apply a step-by-step approach to problem solving in order to improve performance and business metrics for a given scenario

LO2 Analyse customer needs, existing process conditions and required target performance for project scoping in the business

LO3 Apply analytical tools including process capability studies and 5-Whys analysis to determine root cause(s) enabling the process to be improved

LO4 Complete an improvement project by implementing countermeasures with due regards to compliance in line with the set targets.

Essential Content

LO1 **Apply a step-by-step approach to problem solving in order to improve performance and business metrics for a given scenario**

Problem-solving methodologies:

Overview of problem-solving methodologies in engineering and manufacturing: past, current, and future trends and advancements

Toyota 8 Step Practical Problem Solving (TPPS)

Lean 6 Sigma DMAIC

8 Disciplines (8D).

Problem identification:

7 or 8 Wastes and 5-Why

Cost of poor quality (CoPQ)

Is/is not analysis.

Problem solving typical steps:

Clarify the problem (Define)

Break down the problem/set a target (Measure)

Confirm the root cause (Analyse)

Develop and implement countermeasures (Implement)

Evaluate results, standardise and share (Control).

Team approach to problem solving:

Actively promote the case for the adoption of emerging and advanced engineering and manufacturing technologies to problem solving for optimal performance

Comply with statutory and organisational environmental, health and safety regulations and policies at all times

Operate in a systematic, proactive and transparent way

Create and deliver training for application of one or two six sigma tools to those supporting problem-solving activities (e.g. Lean Six Sigma technicians, Yellow Belts or others).

LO2 **Analyse customer needs, existing process conditions and required target performance for project scoping in the business**

Understand customer needs:

Voice of the customer (VoC) analysis

SIPOC (Suppliers, Inputs, Process, Outputs, Customers) diagrams

Stakeholder analysis

RACI matrix

Benchmarking analysis.

Grasp existing process conditions:

Process mapping

Swim lane diagrams

Waste analysis

Developing Smart targets.

Agree the project in the business:

Project selection matrix/scoping tree

Is/is not analysis

Business scorecard

Project charter

Change management techniques

Project management tools (e.g. Gantt chart, toll gate reviews).

LO3 **Apply analytical tools including process capability studies and 5 Whys analysis to determine root cause(s) enabling the process to be improved**

Gather data regarding the problem, visualise and measure impact against standard:

Data collection plan

Histograms, Pareto charts

Scatter diagrams

Box plots.

Use process capability measures and compare before and after improvement:

Principles of measurement: repeatability, reproducibility, linearity, stability

Discrimination (10% rule)

Measurement systems analysis

Types of data: attribute and variable

Measures of central tendency: mean, mode, median, standard deviation

Principles of data normality

Control charts

Common and special cause variation

Process capability measures (Cp/Cpk).

Identify the root cause of the problem:

Cause and effect diagram (Ishikawa/Fishbone)

5-Why analysis

Design of experiment

Failure mode and effects analysis (FMEA).

LO4 **Complete an improvement project by implementing countermeasures with due regards to compliance in line with the set targets**

Confirm root cause(s) and implement improvements:

Pilot study

Pay-off and prioritisation matrices

Countermeasures: identification, selection and evaluation

Compliance requirements: business/customer needs, legal, health and safety, ethical and social; safety first culture

Implementation plan.

Standardise and share learning:

Update process documentation (i.e. SOP, FMEA etc.)

Implement control plans

A3 reporting.

Team sharing and feedback:

Present project improvements to a peer group

Analyse feedback received, create action plans

Execute action and close the loops.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply a step-by-step approach to problem solving in order to improve performance and business metrics for a given scenario		**LO1 and LO2**
P1 Apply correctly all steps of a specified improvement methodology to a given problem. **P2** Perform an improvement activity with due regards to safety and internal and external compliance requirements.	**M1** Develop others in the application of problem-solving tools and methods through support and training.	**D1** Apply steps to promote adoption of continuous improvement principles and tools within the business.
LO2 Analyse customer needs, existing process conditions and required target performance for project scoping in the business		
P3 Evaluate application of problem-solving tools to determine customer needs. **P4** Produce concise and effective project scope with logical SMART goals stated.	**M2** Perform benchmarking (internal and external) to explore opportunities for improvement in a given business scenario.	

Pass	Merit	Distinction
LO3 Apply analytical tools including process capability studies and 5-Whys analysis to determine root cause(s) enabling the process to be improved		**LO3 and LO4**
P5 Collect data in line with a produced data collection plan and accounting for measurement variance. **P6** Apply 5-Why analysis to determine potential root causes	**M3** Perform full process capability study to visually show process true conditions.	**D2** Explore opportunities to replicate improvements made to another function of the business in the current project.
LO4 Complete an improvement project by implementing countermeasures with due regards to compliance in line with the set targets		
P7 Complete a project to meet stated project scope requirements and timescales. **P8** Present the project using a concise, visual format following the steps of a recognised problem-solving methodology.	**M4** Complete the project with a clear and logical flow from one problem-solving step to another, supported by the application/ interpretation of appropriate lean, Six Sigma, project and change management tools.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Bayer, M. (2023) *The 5 Day Lean Six Sigma Green Belt – A Practical Approach to Understanding and Utilizing Lean Six Sigma*.

Brenig-Jones, M. and Dowdall, J. (2022) *Lean Six Sigma for Dummies*. 4th Ed. Hoboken: J Wiley & Sons.

Chen, C. and Roth, H. (2005) *The Big Book of Six Sigma Training Games – Creative Ways to Teach Basic DMAIC Principles and Quality Improvement Tools*. McGraw Hill.

George, M., Rowlands, D., Price, M. and Maxey, J. (2005) *The Lean Six Sigma Pocket Toolbook*. Maidenhead: McGraw Hill.

Pyzdek, T. and Keller, P. (2023) *The Six Sigma Handbook*. 6th Ed. Maidenhead: McGraw Hill.

Rother, M. and Shook, J. (2003) *Learning to See – Value Stream Mapping to Create Value and Eliminate MUDA – A Lean Tool Kit Method and Workbook.* The Lean Enterprise Institute.

Rueda, J. (2022) *Six Sigma Green Belt Study Guide: Prep Book with Practice Test Questions for the ASQ Certification Exam*. 3rd Ed. Test Prep Books.

Salah, S. (2024) *77 Pillars of Quality and the Pursuit of Excellence: A Guide to Basic Concepts and Lean Six Sigma Tools for Practitioners, Managers, and Entrepreneurs* . Routledge.

Smalley, A. (2004) *Creating Level Pull – A Lean Production System Improvement Guide for Production Control, Operations and Engineering Professionals*. The Lean Enterprise Institute.

Tokgoz, E. (2024) *Six Sigma and Quality Concepts for Industrial Engineers – Synthesis Lectures on Engineering, Science, and Technology*. Springer.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Anthony, J. (Editor) *International Journal of Lean Six Sigma*. Emerald Publishing. https://www.emerald.com/insight/publication/issn/2040-4166.

Damodaran, P. (Editor) *International Journal of Six Sigma and Competitive Advantage*. Inderscience Publishers. https://www.inderscience.com/jhome.php?jcode=ijssca.

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4017: Quality and Process Improvement

Unit 4075: Business Improvement Techniques for Engineers

Unit 4077: Lean Techniques for Manufacturing Operations

Unit 5001: Research Project

Unit 5002: Engineering Project Management

Unit 5041: Engineering Project

Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt)

Unit 4111: Powertrain and Hybrid Vehicles

Unit Code: H/651/3069

Level: 4

Credits: 15

Introduction

The automotive engineering landscape is undergoing a revolution as conventional powertrains evolve into hybrids. Seamlessly integrating internal combustion engines with electric motors, these hybrid vehicles present a paradigm shift in redefining efficiency and environmental consciousness. Advancements in battery technology and regenerative braking bolster hybrid powertrains, spurring demand for cleaner transportation. Leading brands like Toyota, Honda and BMW, and startups such as Tesla and Lucid, drive this shift with innovative powertrain solutions, while manufacturers from emerging economies are developing solutions that are more affordable for their markets. Skilled professionals in electric powertrain design, battery management and transmission systems engineering are in high demand as the industry navigates hybrid integration. Their expertise shapes the future of automotive mobility, emphasising the pivotal role of specialised competencies.

The aim of this unit is to introduce students to the key features, operating principles and future developments associated with hybrid vehicles, encompassing not only cars but also larger vehicles such as trucks, buses and agricultural vehicles. Students will delve into the three main combination types: parallel, series and power-split systems, exploring their subsystems alongside current developments in each. Hybrid vehicle powertrains and transmission systems are the focal points of this unit, encompassing a range of different hybrid vehicle layouts, including various motor assistance layouts and the most commonly used placements for motor/mechanical system interfaces.

Topics covered in this unit include: the operation of motors and transmission systems to provide electrical assistance in hybrid vehicles; a range of systems, from simple stop–start mechanisms to fully electric drive systems; and future developments in this field.

Upon successfully completing this unit, students will be proficient in explaining the various approaches to hybrid powertrains for different vehicle types, and the function and operation of drivetrain components, as well as developing an awareness of current and future developments in hybrid vehicle technology.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine the design and function of power and drive systems in hybrid vehicles

LO2 Explore the construction and operation of hybrid vehicle drive systems

LO3 Explore the design and operation of hybrid vehicle transmission systems and subsystems

LO4 Analyse developments in hybrid vehicle powertrain subsystems and their contribution to more efficient vehicles using a first principles approach.

Essential Content

LO1 Examine the design and function of power and drive systems in hybrid vehicles

Overview of hybrid vehicle systems:

Conventional versus modern vehicle systems

Principles and design concepts driving the change

Local and global needs

Competencies, occupation profiles with job roles (e.g. powertrain technician, vehicle calibration analyst, powertrain rig technician).

Drive systems and motor types:

Asynchronous motors (aka induction motors)

Synchronous motors

Brushless motors

Brush-type motors

Synchronous reluctance motor

Spark-ignition engine

Diesel engine

Torque-speed curve

Power–speed curve.

Control system design for drives:

Basics of spark-ignition engine control air–fuel ratios, fuel injection, spark lead-lag timing etc.)

DC motor state space modelling

FOC control of PMSM and IM motors.

Energy storage:

Batteries and cells (18650, 21700, prismatic, blade batteries, 4680)

Primary battery types used: lead–acid, Li-ion (NMC, LFP)

Introduction to design of battery packs (concept of C-rating, series and parallel operation)

Intuition to BMS and battery charging (CC-CV charging)

Chargers (basic topologies and on-board/offboard trade-offs)

Fuel cells

Supercapacitors (e.g. Mercedes AMG MGU-K Unit).

Design features of drive systems:

Stator

Rotor

Housing systems

Driveshafts

Drive gears

One-way clutch

Disconnection clutch

Cooling systems.

LO2 **Explore the construction and operation of hybrid vehicle drive systems**

Hybrid vehicle drive system types:

Stop–start

Mild hybrid

Plug-in hybrid

Strong/full hybrid

Electric vehicles with range extender hybrid.

Hybrid vehicle layouts:

Series

Parallel

Power-split system

Example case studies.

Hybrid vehicle subsystems:

Parallel hybrid single clutch systems

Parallel hybrid two clutch system

Parallel hybrid double clutch transmission

Axle split parallel hybrid

Series hybrid

Series parallel hybrid

Power-split hybrid

Industry case studies.

LO3 **Explore the design and operation of hybrid vehicle transmission systems and subsystems**

First principles approach:

Optimise operations by breaking down a complex system into fundamental parts using essential laws of engineering and physics

Key elements of first principles approach: thermodynamic efficiency, mathematical modelling, control systems, simulation and testing

Applications in powertrains and efficiency vehicles (e.g. combining the first principles of internal combustion engines and electric powertrains to optimise the overall efficiency and performance of hybrid vehicles).

Hybrid vehicle transmission systems and subsystems:

Adapted flywheel drive systems

Transmission motor drive systems

Axle motor drive systems.

Operating principles of hybrid vehicle transmission systems and subsystems:

Drive systems efficiency

Torque production

Regenerative braking systems.

Vehicle types:

Cars and light goods vehicles

Large goods vehicles

Buses and coaches

Commercial vehicles

Agricultural vehicles.

LO4 **Analyse developments in hybrid vehicle powertrains and their contribution to more efficient vehicles**

Technological developments:

Electric turbocharging

Fluid flywheels

Battery technology

Supercapacitors

Mathematical modelling of the powertrain (e.g. fidelity, speed and accuracy levels) using tools and software

Testing paradigms, digital platforms and software tools for testing

Industry case studies.

Regulatory and professional requirements:

EC targets to phase out pure ICE vehicles

Procedural compliance prior to production roll-off

Regional policies, standards and compliance

Professional bodies, international standards.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the design and function of power and drive systems in hybrid vehicles		
P1 Describe the different motor drive systems used in hybrid vehicles. **P2** Explain the characteristics of AC and DC motors used in hybrid vehicles. **P3** Examine the construction and use of different types of motor used in hybrid vehicles.	**M1** Assess the effectiveness of different types of motor for given hybrid motor drive systems.	**D1** Evaluate the efficiency of motor drive systems for a range of hybrid vehicle applications.
LO2 Explore the construction and operation of hybrid vehicle drive systems		
P4 Explore the design and layout of a range of hybrid drive systems. **P5** Explore the operation of a range of hybrid drive subsystems and how these interact with other powertrain components.	**M2** Review the types of hybrid vehicle and the subsystems that are incorporated to develop efficient vehicles.	**D2** Evaluate the efficiency of hybrid vehicle drive systems with respect to the location of components and the type of drive employed.

Pass	Merit	Distinction
LO3 Explore the design and operation of hybrid vehicle transmission systems and subsystems		
P6 Explore the design of a range of hybrid vehicle transmission layouts. **P7** Analyse the operating principles of hybrid vehicle transmission systems.	**M3** Assess the effectiveness of a range of hybrid vehicle transmission types for different types of vehicles.	**D3** Evaluate the efficiency of a range of hybrid vehicle transmission layouts for given vehicle applications.
LO4 Analyse developments in hybrid vehicle powertrains and their contribution to more efficient vehicles		
P8 Analyse the developments in technology that can improve the efficiency of hybrid vehicles. **P9** Describe the regulatory challenges that will affect the market for hybrid vehicles.	**M4** Assess the approaches that can be used to lead to improvements in the efficiency of hybrid vehicles.	**D4** Evaluate the benefits and challenges associated with current and future hybrid vehicle design.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Ehsani, M., Gao, Y. and Emadi, A. (2009) *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design.* 2nd Ed. Power Electronics and Applications Series. Boca Raton, FL: CRC Press.

Gleason (2020) *EDrive Transmission Guide: New Solutions for Electric and Hybrid Vehicle Transmissions*. Gleason Works.

Leonhard, W. (2001) *Control of Electrical Drives.* 3rd Ed. Berlin: Springer.

Mi, C. and Masrur, M. (2017) *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*. John Wiley & Sons.

Perkins, P. (2021) *The Future of Hybrid Cars*. Editora Bibliomundi.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

(2024) 'A comprehensive review on hybrid electric vehicles: Architectures and components', *Railway Engineering Science*, Springer. Available at: https://link.springer.com/article/10.1007/s40534-024-00234-6.

McKinsey & Company (2024) 'Why the future involves e-mobility'. Available at: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-the-future-involves-e-mobility.

MDPI (2024) 'Design of a Hybrid Electric Vehicle Powertrain for Performance Optimization Considering Various Powertrain Components and Configurations'. Available at: https://www.mdpi.com/vehicles/vehicles1010124.

Skill-Lync (2024) 'Future of hybrid electric vehicles: Advances in Technology and Sustainability'. Available at: https://skill-lync.com/research/future-of-hybrid-electric-vehicles-advances-in-technology-and-sustainability.

International Journal of Electric and Hybrid Vehicles, Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijehv.

SAE International Journal of Electrified Vehicles, SAE International. Available at: https://www.sae.org/publications/journals/content/jev/.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4092: Vehicle Dynamics and Performance

Unit 4093: Race Car Design and Manufacturing

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 5058: Automotive Structures and Materials

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 4112: Vehicle Repair and Diagnostics

Unit Code: **L/651/3070**

Level: **4**

Credits: **15**

Introduction

As vehicles become more advanced and interconnected, the role of the modern vehicle mechanic evolves, requiring a blend of traditional mechanical prowess with cutting-edge diagnostic skills. Vehicle mechanics and technicians are pivotal in ensuring the smooth functioning and safety of automobiles, tackling tasks from routine maintenance to diagnosing complex electrical faults. With advancements in diagnostic technologies such as OBD-II scanners and sophisticated software tools, mechanics can quickly identify issues, so reducing diagnostic times and improving repair accuracy. The integration of IoT enhances real-time monitoring and predictive maintenance. Example job roles now include traditional mechanics, automotive diagnostic technicians and electric vehicle specialists. Major players such as Bosch, Snap-on, and Siemens lead in developing innovative diagnostic tools, while the future of vehicle repair points towards AI and machine learning for more precise diagnostics and automated processes.

The aim of this unit is to equip students with the fundamental knowledge and practical skills essential for excelling in the dynamic field of automotive technology. By delving into both the mechanical and electrical aspects of vehicle maintenance and diagnostics, students will attain a comprehensive understanding of the inner workings of automobiles and performance assessment aspects of vehicle systems operation and testing. Through a combination of theoretical study and hands-on practical exercises, students will develop proficiency in inspecting, repairing and maintaining various mechanical components, such as engines, transmissions, brakes and suspension systems. Additionally, they will learn to diagnose and troubleshoot complex electrical and electronic issues using state-of-the-art diagnostic tools and software.

On successful completion of this unit, students will be well prepared to succeed in the automotive industry, having developed a well-rounded skill set encompassing both mechanical and electrical aspects of vehicle repair and diagnostics.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Demonstrate proficiency in inspecting automotive mechanical systems

LO2 Apply appropriate repair and maintenance techniques to address mechanical issues efficiently, ensuring the optimal performance and safety of vehicles

LO3 Utilise diagnostic tools and techniques effectively to identify and diagnose complex electrical and electronic faults in vehicle systems

LO4 Apply systematic troubleshooting methodologies to isolate and rectify electrical faults, ensuring the proper functioning of electrical components and systems within vehicles.

Essential Content

LO1 **Demonstrate proficiency in inspecting automotive mechanical systems**

Overview of vehicle repairs and diagnostics:

Role of vehicle mechanic and technicians, modern systems and diagnostic technologies (e.g. OBD-II scanners), software tools, IoT and real-time monitoring, innovation from major industry players, adaptation of these innovations by the small companies and how they may implement them

Future trends in using AI and machine learning

Occupation profiles and job roles.

Mechanical systems:

Inspection techniques used for engines, transmissions, after-treatment systems, brakes and suspension components

Operating parameters of engines including SI and CI combustion

Transmission usage and effective matching of vehicle to speed requirements e.g. manual and automatic transmissions including dual clutch and continuously variable transmission systems

Suspension components and their behaviour

Brake components, size and materials used for appropriate performance.

Service and maintenance:

Service schedules

Effective life prolonging inspection and maintenance

Wear of components and materials

Repair recommendations including replacement, adjustment and repair

Justifications for repair recommendations.

Malfunctions and fault finding:

Diagnostic techniques and equipment

Fault finding and symptom location, fault location guides

Presentation of findings.

LO2 **Apply appropriate repair and maintenance techniques to address mechanical issues efficiently, ensuring the optimal performance and safety of vehicles**

Safety first culture:

Justification of repair processes in terms of reliability, safety and cost

Appropriate diagnostic of faults and after-repair processes to ensure appropriate repair and safety for the vehicle and system

Manufacturer recommendations for maintenance and repair of mechanical systems.

Repair and maintenance of performance and emission systems:

Turbo and supercharging systems

Exhaust gas recirculation (EGR)

Variable valve timing

Exhaust after-treatment systems including catalysts, diesel particulate filters, selective catalytic reduction systems.

Performance:

Improvements, updates or recalls enhancing vehicle performance

Appropriate after-repair procedures to check for optimal performance and to ensure additional life of systems.

LO3 **Utilise diagnostic tools and techniques effectively to identify and diagnose complex electrical and electronic faults in vehicle systems, LO2 vehicle systems and technology**

Electrical and electronic systems:

Correct operating principles of ignition systems and their components

Correct operating principles of fuel injection systems and their components

Engine control units, sensor and actuator operating parameters, main and compensation maps and appropriate functionality

Vehicle mechanical system electronic control units and their operation to enhance vehicle stability and/or safety

ABS, traction control, stability control, active suspension and their operation

Alternator and charging systems.

Diagnostic tools:

Control unit interrogation

The use of oscilloscopes, multimeters and power probes to effectively diagnose electrical/electronic malfunctions and incorrect signals

Data logging and analysis to monitor failing systems and correctly functioning components.

Diagnostic procedures:

Manufacturer checking procedures

Sensor and actuator data sheets

Appropriate fault-finding techniques and systemic fault diagnosis.

LO4 **Apply systematic troubleshooting methodologies to isolate and rectify electrical faults, ensuring the proper functioning of electrical components and systems within vehicles**

Malfunctioning systems:

Diagnosis of systems and correct identification of faults compared to known functioning results, signals and operation

Correct isolation of malfunctioning system and appropriate steps to identify failing components

Factors that contribute to diagnosis e.g. logical process, diagnostic and specialist equipment required, on-board computer-based and telemetry diagnostic systems, equipment costs, likely time saving, ability to upgrade, ease of use, manufacturers' back-up, workshop manuals, technical bulletins.

Identifying and testing appropriate repair:

After-repair diagnostics, evaluating repair and ensuring system responsiveness

Application of fault diagnosis techniques, appropriate justifications of repair, quality control of repair and final sign-off of completed work

Repair procedure and diagnosis justifications, presentation of results and tests

Technical reports

Fault location guide: prepared for a given vehicle system and including expected test readings, description of the system with an explanation of its use, theory of operation, instruments and special tools required, test instructions, step-by-step fault location guide to fault diagnostic procedure.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Demonstrate proficiency in inspecting automotive mechanical systems		**LO1 and LO2**
P1 Analyse a diagnosis specification for a mechanical vehicle system. **P2** Demonstrate competence in diagnosing the specification of an electrical/electronic vehicle system that controls a mechanical system.	**M1** Carry out an inspection and systematic fault diagnosis on at least two mechanical systems.	**D1** Produce a written report of the test results, diagnostic steps taken and repair recommendations.
LO2 Apply appropriate repair and maintenance techniques to address mechanical issues efficiently, ensuring the optimal performance and safety of vehicles		
P3 Apply repair techniques to mechanical systems following the identification of failures. **P4** Produce an appropriate report explaining diagnosis, repair and test of mechanical systems.	**M2** Explain how repair or replacements of components ensures safety and optimal performance of a vehicle mechanical system.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Utilise diagnostic tools and techniques effectively to identify and diagnose complex electrical and electronic faults in vehicle systems</td><td rowspan="4">LO3 and LO4

D2 Create an effective fault location guide for diagnosis of an electrical/electronic system.</td></tr>
<tr><td>P5 Utilise appropriate test equipment for a given scenario.

P6 Carry out a systematic fault diagnosis for a given scenario.</td><td>M3 Explain repair recommendations following interpretation of faults from the given symptoms</td></tr>
<tr><td colspan="2">LO4 Apply systematic troubleshooting methodologies to isolate and rectify electrical faults, ensuring the proper functioning of electrical components and systems within vehicles</td></tr>
<tr><td>P7 Apply repair techniques to electrical/electronic systems following the identification of failures.

P8 Interpret faults and incorrect readings with a justification of the test results in terms of the known data for that system.</td><td>M4 Explain how repair or replacements of components ensures safety and optimal performance of a vehicle electrical system.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Beiker, S. (2021) *Automotive Technology: Principles, Diagnosis, and Service.* 6th Ed. Upper Saddle River, NJ: Pearson.

Birch, T. (2021) *Automotive Engine Performance.* 5th Ed. Clifton Park, NY: Cengage Learning.

Bosch, R. (2021) *Bosch Automotive Handbook.* 10th Ed. Warrendale, PA: SAE International.

Denton, T. (2022) *Automobile Mechanical and Electrical Systems.* 3rd Ed. Oxon: Routledge.

Denton, T. (2020) *Advanced Automotive Fault Diagnosis: Automotive Technology: Vehicle Maintenance and Repair.* 5th Ed. Oxon: Routledge.

Duffy, J.E. (2015) *Auto Engine Repair.* 6th Ed. Tinley Park, IL: Goodheart-Willcox.

Duffy, J.E. (2020) *Modern Automotive Technology.* 10th Ed. Tinley Park, IL: Goodheart-Willcox.

Halderman, J.D. (2017) *Automotive Technology: Principles, Diagnosis, and Service.* 5th Ed. Upper Saddle River, NJ: Pearson.

Journals and articles

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Li, S., Frey, M. and Gauterin, F. (2023) 'Evaluation of different fault diagnosis methods and their applications in vehicle systems', *Machines*, 11, p. 482. Available at: https://doi.org/10.3390/machines11040482.

IEEE Transactions on Vehicular Technology. Available at: https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=25.

International Journal of Automotive Technology. Available at: https://www.springer.com/journal/12239.

Journal of Power Sources. Available at: https://www.journals.elsevier.com/journal-of-power-sources.

Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. Available at: https://journals.sagepub.com/home/pia.

SAE International Journal of Passenger Cars – Mechanical Systems. Available at: https://www.sae.org/publications/journals/content/1001.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4093: Race Car Design and Manufacturing

Unit 4096: Automotive Workshop Practices

Unit 5060: Motorsport Workshop Preparation and Inspection

Unit 4113: Heavy Vehicles I

Unit Code: M/651/3071

Level: 4

Credits: 15

Introduction

Heavy vehicles are crucial for transporting people and goods from one location to another. Although this is a general term for larger vehicles, heavy vehicles differ significantly in design from light vehicles in numerous ways. They are fundamental to automotive engineering, supporting logistics, construction and public transport globally. These include trucks, buses and commercial vehicles, which are essential for efficient transportation, driving economic growth. As the focus on vehicle sustainability intensifies, the industry is seeing a shift towards electric and hydrogen-powered heavy vehicles. However, significant skills gaps persist, particularly in high-voltage technology, battery solutions, sustainable energy solutions and advanced vehicle systems such as powertrain management and emissions control. Leading industry innovators such as Volvo, Scania and Daimler are pioneering these technologies. Graduates in this field may take on roles as design engineers, systems analysts or sustainability managers, which need a blend of engineering principles and knowledge of cutting-edge technologies such as autonomous driving systems and advanced diagnostics. This dynamic sector offers vast opportunities for professionals looking to make a tangible impact on the future of transportation.

The aim of this unit is to introduce the systems that need to be considered when designing a heavy vehicle. Through analysis of case studies on industry leaders as well as the roles and needs of the SMEs, students will understand the complexities of heavy vehicle engineering.

Topics covered in this unit include: the design of chassis and suspension systems; rigid and articulated vehicles; engines, gearboxes, braking systems and steering systems; drivetrain/powertrain systems and emissions in designing heavy vehicles.

On successful completion of this unit, students will have a comprehensive understanding of how various systems and design features work together to ensure the safe and efficient operation of heavy vehicles. Knowledge and skills gained will prepare them to contribute effectively to the design and innovation of future heavy vehicle systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine heavy vehicle chassis and suspension designs

LO2 Explore heavy vehicle engine and transmission systems

LO3 Examine heavy vehicle braking systems

LO4 Investigate heavy vehicle steering systems.

Essential Content

LO1 **Examine heavy vehicle chassis and suspension designs**

Overview of heavy vehicles industry:

The evolution of heavy vehicles

The role, typical usage, classification and types of heavy vehicles

Design considerations and variations in local and global contexts

Needs and role of small to medium size enterprises (SMEs)

Legal framework (e.g. ECE R13), regulations and compliance

Relevant industry (e.g. IATF 16949) and professional standards (e.g. UK-SPEC).

Types of chassis:

Rigid chassis

Articulated vehicles

Trailer systems

Multi-axle vehicles.

Drive arrangements:

Twin-wheel drive

All-wheel drive.

Suspension types:

Leaf spring suspension systems

Pneumatic suspension systems

Rubber suspension systems.

Chassis, drive and suspension design considerations:

Axle load calculations

Payload distribution plans

Width requirement (e.g. when cornering)

Tipping limits.

LO2 Explore heavy vehicle engine and transmission systems

Engines:

Layouts and configurations

Capacity and number of cylinders

Fuel types

Common rail direct injection

Turbo charged direct injection

Multi-point fuel injection

Emission control.

Clutches:

Principle clutch components

Types of clutch

Torque converters

Engagement and disengagement of clutches

Design and construction

Materials.

LO3 Examine heavy vehicle braking systems

Design considerations for braking systems:

Stability under braking for different vehicle configurations.

Brake actuation systems:

Air-brake actuators

Parking brake systems

Brake clearance adjustments.

Brake control systems:

Foot valve

Hand control

Relay control

Pressure protection systems.

Air-brake and air-over-hydraulic systems:

Full, split and duel braking systems

Hydraulic circuits

Parking brakes

Remote spring brakes.

LO4 **Investigate heavy vehicle steering systems**

Manual and power assisted steering systems:

Single and twin steer axle systems

Rear axle steering systems.

Manual steering system components:

Steering boxes

Steering linkages for single- and twin-steer systems

Steering wheel and column design.

Power assisted steering system components:

Hydraulic pump types and operation

Hydraulic system components.

Steering geometry

Non-steering axles

Wheel alignment

Steering geometry set-up.

Industry case studies:

A selection of case studies from local SMEs and large global players (e.g. Volvo, Mercedes Benz, Mitsubishi, Ford, Leyland Trucks, Tata Motors).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine heavy vehicle chassis and suspension designs		
P1 Examine alternative chassis design layouts that are used for heavy vehicles. **P2** Explain the layouts and designs of drive systems for different types of heavy vehicle. **P3** Explain the design and use of different suspension types for heavy vehicles.	**M1** Assess the design of vehicle chassis, drive and suspension systems for a given type of heavy vehicle.	**D1** Evaluate alternative chassis, drive and suspension systems for a range of different types of heavy vehicle
LO2 Explore heavy vehicle engine and transmission systems		
P4 Assess the types of engines that are used for two different heavy vehicle types. **P5** Explore the components and operation of a heavy vehicle transmission system.	**M2** Analyse the efficiency and operation of heavy vehicle engines and transmission systems for passenger and goods vehicles.	**D2** Evaluate the function, operation and efficiency of engines and gearboxes for passenger and goods vehicles.
LO3 Examine heavy vehicle braking systems		
P6 Discuss the function and operation of full air braking systems for specific heavy vehicle types. **P7** Examine the application of air-over-hydraulic braking systems for heavy vehicles.	**M3** Assess the use of full air braking systems and air-over-hydraulic systems for specific heavy vehicle types.	**D3** Evaluate the effectiveness of different types of braking system for specific heavy vehicle types.
LO4 Investigate heavy vehicle steering systems		
P8 Investigate the operation of manual steering systems for heavy vehicles. **P9** Discuss the principles of operation of power assisted steering systems for heavy vehicles.	**M4** Assess the construction and operation of steering systems for passenger and goods vehicles.	**D4** Evaluate the function and operation of heavy vehicle steering systems for given passenger and goods vehicles.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Belousov, B. and Popov, S. (2014) *Heavy-Duty Wheeled Vehicles: Design, Theory, Calculations*. SAE International.

Genta, G. and Morello, L. (2019) *The Automotive Chassis: Volume 1: Components Design*. Springer Nature.

Genta, G. and Morello, L. (2019) *The Automotive Chassis: Volume 2: System Design*. Springer Nature.

Hilgers, M (2023) *Chassis and Axles*. Springer Nature.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Abdulkadir Yasar and Durmus Ali Bircan. 'Design, analysis and optimization of heavy vehicle chassis using finite element analysis', *ResearchGate*. Available at: https://www.researchgate.net/publication/341434935_Design_Analysis_and_Optimization_of_Heavy_Vehicle_Chassis_Using_Finite_Element_Analysis.

Sanchit Shrivastava, Roopesh Tiwari, Suman Sharma. 'Design and analysis of heavy commercial vehicle chassis through material optimization', *International Journal of Engineering Trends and Technology (IJETT)*. Available at: https://www.ijettjournal.org/.

Srilatha, J. 'Design and analysis of heavy-duty vehicle truck chassis', *ResearchGate*. Available at: https://www.researchgate.net/publication/341519129_Design_and_analysis_of_heavy_duty_vehicle_truck_chassis.

eBooks

Transportation Research Board. (2002) *Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles (Special Report 67)*. Available at: https://www.trb.org/publications/sr/sr267.pdf.

US Federal Highway Administrators Freight Management and Operations. (2004)

Freight Size Regulations for Commercial Motor Vehicles. Available at: https://ops.fhwa.dot.gov/freight/publications/size_regs_final_rpt/.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4092: Vehicle Dynamics and Performance

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 5058: Automotive Structures and Materials

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 5071: Heavy Vehicles II

Unit 4114: Motorcycle Engineering

Unit Code: R/651/3072

Level: 4

Credits: 15

Introduction

In the UK, motorcycling accounts for approximately 1% of the total road traffic, with an estimated 1.5 million active motorcyclists. The industry sees the sale of over 100,000 new two-wheeled powered vehicles annually, contributing to a total turnover exceeding £5 billion. Many of these riders are passionate enthusiasts with extensive knowledge about their motorcycles who expect the supply chain network to share their passion and expertise. To meet these high expectations, the industry aims to recruit and train competent and skilled technicians. Educating technicians to a high level will enable them to handle the complex and sophisticated motorcycles prevalent on the roads today.

The aim of this unit is to develop the knowledge and understanding of motorcycle design, engineering and operation by investigating the various forms and functions of two-wheeled vehicle design including the physical and dynamic constraints on how motorcycles operate.

Among the topics taught in this unit are: fundamentals of motorcycle engineering including frame and steering geometry, effects of lateral and longitudinal forces, low- and high-speed dynamics, ergonomics and the effect the rider has on stability; variants in two-wheeled powered vehicle design including power 2-stroke, 4-stroke, single or multiple cylinders; and battery power and supporting systems (frames, brakes, suspension, electronic aids).

On successful completion of this unit, students will be able to apply fundamental knowledge and understanding of motorcycle design including dynamic forces, propulsion technology, rider ergonomics and the design intent behind the variety of motorcycles. Students will also develop an understanding of various elements of motorcycle technology such as types of motive power, braking, suspension and steering systems, and electronic systems including emissions control.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Define the dynamic forces encountered by a motorcycle

LO2 Discuss the design geometry of a variety of motorcycles

LO3 Demonstrate knowledge of the motive power of motorcycles

LO4 Examine the key aspects of motorcycle engineering.

Essential Content

LO1 **Define the dynamic forces encountered by a motorcycle**

The motorcycle sector:

Industry overview, regional needs, history and progression of motorcycle engineering, future advancements, careers within the sector, occupational standards within the sector, government regulations and licencing requirements, professional accreditations.

Longitudinal forces:

Accelerating

Braking

Gyroscopic effect.

Lateral forces:

Low-speed cornering

High-speed cornering

Lean angles.

Environmental and ergonomic forces:

Effects of wind, gradient, rolling, air composition

Effects of rider position.

LO2 **Discuss the design geometry of a variety of motorcycles**

Styles and types of motor cycles:

Mopeds

Small motorcycles

Tourers, cruisers

Performance, adventure/ dual purpose

Dedicated off-road.

Steering geometry:

Wheelbase

Rake

Fork offset

Mechanical trail/normal trail.

Rider ergonomics:

Riding position for a moped, tourer or performance bike, rearward view

Handlebar design and controls, cockpit design, display types accessibility view and glare reduction

Seat design and foot controls/Critical seat heights

Clothing, regional and global variations in rider attire.

LO3 **Demonstrate knowledge of the motive power of motorcycles**

2-strokes and 4-strokes internal combustion (IC) engines:

2-stroke operation single cylinder

4-stroke operation single cylinder

Multi-cylinder configurations

Variations.

Gear boxes and clutches:

Manual gear box

Automatic gear box

Manual clutches

Automatic clutches

Chain drive and shaft drive

Belt drives.

Alternative motive power:

Electrical

Hydrogen

Alternative fuels for ICE petroleum E ratings.

LO4 **Examine the key aspects of motorcycle engineering**

Suspension:

Front fork designs, damping and adjustment

Rear suspension design twin shock absorbers and mono-shocks

Electronics (ABS, Rider MODES, Emissions).

Brakes, tyres and wheels:

Brakes: disc brake, caliper design, drum brakes, anti-lock braking system (ABS)

Wheel design and geometry

Tyre design and function, contact patch and profile variants, tread design and compounds.

Motorcycle electronics:

Ignition systems electronic and electromechanical

Rider aids

Subsidiary systems: lights, indicators

Fuel mapping emissions.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Define the dynamic forces encountered by a motorcycle</td><td rowspan="4">LO1 and LO2

D1 Critically evaluate how motorcycle design has developed into the vehicles we see today and how that may develop in the future.</td></tr>
<tr><td>P1 Describe the development of motorcycle design and the effect on performance.

P2 Define the effects of longitudinal and lateral forces on a motorcycle.</td><td>M1 Evaluate the change in performance of motorcycles over time including the increased variation in design types.</td></tr>
<tr><td colspan="2">LO2 Discuss the design geometry of a variety of motorcycles</td></tr>
<tr><td>P3 Discuss the variations in motorcycle design including how the intended purpose dictates overall geometry.

P4 Discuss the impact of rider ergonomics on motorcycle design including global variations.</td><td>M2 Assess the effect that changes in geometry has on motorcycle design and how these have an impact on the overall safety of the vehicle.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Demonstrate knowledge of the motive power of motorcycles		**LO3 and LO4**
P5 Explain the significant differences between motorcycle internal combustion engine operation and configuration. **P6** Demonstrate knowledge of the operation of a variety of motorcycle transmission systems.	**M3** Explore the effect on application of combining engine and transmission systems.	**D2** Critically analyse the effect of increasing power has on the selection elements within a motorcycle and how this may inform future design.
LO4 Examine the key aspects of motorcycle engineering		
P7 Examine the main variations in braking and suspension systems. **P8** Explain the effect electronic rider aids has on rider safety and motorcycle efficiency.	**M4** Evaluate the need for more efficient and complex braking suspension and electronic systems as motorcycles increase in power.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Briora, G. A. (2022) *Motorcycle Geometry and Suspension Adjustment.* GA Academy.

Foale, T. (2006) *Motorcycle Handling and Chassis Design: The Art and Science*. Tony Foale Designs.

Inman, G. and Adi, G. (2020) *How to Build a Motorcycle: A Nut-and-Bolt Guide to Customizing Your Bike.* Orion Publishing Co.

Livesey, A. (2021) *Motorcycle Engineering*. London and New York: Routledge.

Lot, R. and Sadauckas, J. (2021) *Motorcycle Design Vehicle Dynamics Concepts and Applications*. Lulu Press.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

International Journal of Motorcycle Studies. Available at: https://motorcyclestudies.org/.

International Journal of Vehicle Design. Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijvd.

Journal of Mechanical Engineering. Available at: https://journals.sagepub.com/home/jme.

Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. Available at: https://journals.sagepub.com/home/pia.

SAE International Journal of Transportation Safety. Available at: https://www.sae.org/publications/journals/content/10.4271/10-02-01-0001.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4092: Vehicle Dynamics and Performance

Unit 5058: Automotive Structures and Materials

Unit 5070: Further Motorcycle Engineering

Unit 4115: Vehicle Electrical and Electronics

Unit Code: T/651/3073

Level: 4

Credits: 15

Introduction

The increasing use of electronic circuitry in motor vehicle control systems has contributed to advances in design and functionality, driving significant advances in safety, comfort, fuel economy and overall performance. Applications incorporating microprocessor hardware networks continue to evolve, as do hybrid and electric vehicle technologies. Therefore, it is essential for motor vehicle engineers to be familiar with the operation of electronic circuits and with methods of fault diagnosis communication protocols, which help to understand the diagnosis.

The aim of this unit is to equip students with the knowledge, practical skills and behaviours required in the field of automotive electrical and electronic systems and technologies, which are found within a broad range of modern vehicles including hybrid and purely electric vehicles such as light or heavy vehicles, trucks and buses.

Topics covered include: electronic principles, circuit components and test procedures; various types of sensors, actuators and display units used in motor vehicle control and driver information systems; microprocessor hardware applications and the suppression methods used to prevent interaction between systems; systematic testing and fault diagnosis of vehicle control and information systems; and key components and systems found in hybrid and electric vehicles.

On successful completion of this unit, students will have attained theoretical knowledge and a practical understanding of vehicle electrical and electronic systems. The unit will enable students to specialise in vehicle maintenance, system diagnostics or the emerging field of electric and hybrid vehicle technology, and it will equip them with the skillset needed to excel in the automotive industry.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Analyse vehicle electrical and electronic circuits in a range of contexts

LO2 Examine the operation of vehicle sensors, actuators and display units

LO3 Examine the operation of microcontroller hardware and suppression methods used in vehicle circuits

LO4 Describe the key components and safety considerations found in hybrid and electric vehicles.

Essential Content

LO1 **Analyse vehicle electrical and electronic circuits in a range of contexts**

Essentials of vehicle electrical and electronics:

Key components (e.g. batteries, alternators, sensors actuators, microcontrollers for engine management, transmission control, battery management systems, CAN bus, networking of microcontrollers)

Diagnostics and troubleshooting

Past, current and future developments

Real-world contexts and problems

Occupations, professional roles and competencies (e.g. vehicle analyst, maintenance technician, motorsport engineer, incorporated engineer).

Electrical calculations:

Voltage

Emf

Current

Power

Resistance

Capacitance

Inductance

Series and parallel circuits.

Semiconductor devices:

Electrical properties and characteristics of semiconductor materials: P-N junction diode, Zener diode, N-P-N junction transistor, P-N-P junction, transistor and thyristor

Analyse the operation of a semiconductor-based circuit e.g. electronic ignition amplifier or fly-back diode.

Circuit diagrams:

Electrical and electronic component and circuit symbols

Circuit diagram layouts.

Systematic testing:

Test procedures: correct use of multimeters and oscilloscope for measuring circuit and component values; use of other simulation/ lab tools.

LO2 **Examine the operation of vehicle sensors, actuators, and display units**

Sensors:

Sensor selection, and operating conditions, principles of operation and electrical characteristics of sensors used in vehicles e.g. sensors used in anti-lock braking systems (ABS), electronic fuel injection (EFI), ignition timing, engine management systems, airbags, security, driver information and vehicle condition monitoring systems)

Relevant test procedures for sensors.

Actuators:

Principles of operation and electrical characteristics of vehicle actuators e.g. relays, solenoids, electro-hydraulic/pneumatic valves, rotary actuators, stepper motors

Relevant tests procedures for actuators.

Information display devices:

Types of devices e.g. analogue and digital gauges, in-car entertainment (ICE), light emitting diodes, LCD and TFT displays, vacuum fluorescent displays, cathode ray tubes

Relevant test procedures for displays

Selection criteria for displays based on the safety regulations.

LO3 **Examine the operation of microcontroller hardware and suppression methods used in vehicle circuits**

Microcontroller hardware:

Implementation, operation and networking of microcontroller systems in vehicles e.g. engine management system (EMS), selection of controller area network (CAN) bus and local interconnected network (LIN) bus

Automotive ethernet

Packaging

CAN bus message structure

Microprocessors

Integrated circuits

Reliability

Electromagnetic compatibility

Wiring topologies.

Suppression methods:

Resistive suppression of oscillations

Screening

Use of inductors

Capacitors

Diodes and filter networks in interference suppression.

Systematic testing and diagnostics:

Testing of input/output sensors, cables, supplies, earths, output actuators e.g. continuity checks

Sensor output

Resistance checks

Display devices, microprocessor systems, use of real-time and logged data Open and short circuit checks

OBD error/trouble codes

Standardisation of connectors and codes

CAN simulation with Vector tool or Peak CAN

MATLAB simulation for CAN messaging.

LO4 **Describe the key components and safety considerations found in hybrid and electric vehicles**

Key components:

High-voltage (HV) battery, resolver, HV cables, DC/DC converter, inverter, permanent magnet synchronous motor/generator, battery management system (BMS)

Battery balancing, temperature control, error codes

Flow chart preparation for start and shutdown sequence of operation of battery packs and vehicle.

Health and safety considerations and compliance:

Safety first culture, working with high voltage, de-energising HV systems, test procedures, personal protective equipment (PPE)

Design considerations for battery selection

HV batteries and their operating conditions

Guidelines and regulations of battery packs, material safety data seer (MSDS) and its importance

Organisational health and safety policies and regulations, environmental and human factors, compliance, application through active promotion.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse vehicle electrical and electronic circuits in a range of contexts		**LO1 and LO2**
P1 Analyse automotive electrical and electronic circuit diagrams by interpreting these for a given scenario. **P2** Conduct calculations to solve problems in series and parallel automotive electrical circuits.	**M1** Explain the properties and characteristics of common semiconductor devices.	**D1** Perform systematic testing of vehicle electronic systems, sensors and actuators and analyse the results.
LO2 Examine the operation of vehicle sensors, actuators and display units		
P3 Explain the principles of operation and electrical characteristics of three different types of sensors when used in vehicles. **P4** Examine of operation and electrical characteristics of three different types of actuators when used in vehicles.	**M2** Justify the use of a one type of sensor and one type of actuator for a specific application within a vehicle.	

Pass	Merit	Distinction
LO3 Examine the operation of microcontroller hardware and suppression methods used in vehicle circuits		**LO3 and LO4** **D2** Compare the role of the battery management system with the role of an engine management system.
P5 Explain microcontroller hardware and system operations within a vehicle. **P6** Examine the operation of a suppression method used with a microcontroller system.	**M3** Conduct systematic test procedures on an engine management system and record results.	
LO4 Describe the key components and safety considerations found in hybrid and electric vehicles		
P7 Describe the key components found in a hybrid or electric vehicle. **P8** Describe the safety procedures and regulations involved when working with high-voltage vehicle systems.	**M4** Investigate the EV/hybrid electrical and electronic systems found in a specific vehicle.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Boylestad, R.L. and Nashelsky, L. (2013) *Electronic Devices and Circuit Theory*. 11th Ed. Pearson.

Brown, C. (2011) *Making Sense of Squiggly lines*. Huntington Beach: Christopher Brown Racing.

Denton, T. (2017) *Automobile Electrical and Electronic Systems*. 5th Ed. London: Routledge.

Denton, T. (2021) *Advanced Automotive Fault Diagnosis*. 5th Ed. London: Routledge.

Floyd, T.L. and Buchla, D. (2013) *Electronics Fundamentals: Circuits, Devices & Applications*. 8th Ed. Pearson.

Horowitz, P. and Hill, W. (2015) *The Art of Electronics*. 3rd Ed. Cambridge University Press.

Ibrahim, I. (2012) *Controller Area Network projects.* Susteren: Elektor.

Ribbens, W. (2017) *Understanding Automotive Electronics*. 8th Ed. Saint Louis: Elsevier Science.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Automotive Technology – Electrical and Electronics. Available at: https://www.automotive-technology.com/electrical-electronics.

International Journal of Automotive Technology. Available at: https://www.springer.com/journal/12239.

International Journal of Electric and Hybrid Vehicles. Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijehv.

SAE International Journal of Passenger Cars—Electronic and Electrical Systems. Available at: https://www.sae.org/publications/journals/content/10.4271/10-02-01-0001.

World Electric Vehicles Journal. Available at: https://www.mdpi.com/journal/wevj.

Links

This unit links to the following related units:

Unit 4021: Electrical and Electronic Principles

Unit 4026: Electrical Systems and Fault Finding

Unit 5013: Embedded Systems

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit 5069: Vehicle Systems and Technologies

Unit 5001: Research Project

Unit Code: J/615/1502

Level: 5

Credits: 30

Introduction

Completing a piece of research is an opportunity for students to showcase their intellect and talents. It integrates knowledge with different skills and abilities that may not have been assessed previously, which may include seeking out and reviewing original research papers, designing their own experimental work, solving problems as they arise, managing time, finding new ways of analysing and presenting data, and writing an extensive report. Research can always be a challenge but one that can be immensely fulfilling, an experience that goes beyond a mark or a grade, but extends into long-lasting areas of personal and professional development.

This unit introduces students to the skills necessary to deliver a complex, independently conducted research project that fits within an engineering/ manufacturing context.

On successful completion of this unit, students will be able to deliver a complex and independent research project in line with the original objectives, explain the critical thinking skills associated with solving engineering/manufacturing problems, consider multiple perspectives in reaching a balanced and justifiable conclusion, and communicate effectively a research project's outcome. Therefore, students develop skills such as critical thinking, analysis, reasoning, interpretation, decision-making, information literacy, information and communication technology literacy, innovation, conflict resolution, creativity, collaboration, adaptability, and written and oral communication.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine the preliminary stages involved in the creation of an engineering/manufacturing research project

LO2 Examine the analytical techniques used to work on all stages of the project and strategies required to overcome the challenges involved in a research project

LO3 Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering/manufacturing context

LO4 Explore the communications approach used for the preparation and presentation of the research project's outcomes.

Essential Content

LO1 **Examine the preliminary stages involved in the creation of an engineering/manufacturing research project**

Setting up the research preliminaries:

Project proposal (note: relevant to the subject of study)

Developing a research question(s)

Selection of project approach and use of relevant research methods (e.g., statistical analysis, surveys, etc.)

Identification of project supervisor

Estimation of resource requirements, including possible sources of funding

Setting key project objectives, goals, and rationale

Stakeholder requirements if any

Development of project specification.

LO2 **Examine the analytical techniques used to work on all stages of the project and strategies required to overcome the challenges involved in a research project**

Investigative skills and project strategies:

Key research methods and rationale, primary and secondary research

Selecting the method(s) of collecting data

Data analysis and interpreting findings

Literature review (e.g., journals and published papers)

Engaging with technical literature (e.g., industry case studies, engineering/manufacturing data reports, professional body publications)

Technical depth

Multi-perspectives analysis

Independent thinking

Statement of resources required for project completion

Potential risk issues, including health and safety, environmental and commercial

Project management and key milestones.

LO3 **Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering/manufacturing context**

Research purpose:

Detailed statement of project aims

Relevance of the research

Benefits and beneficiaries of the research

Professional, legal, social, and ethical aspects of research.

LO4 **Explore the communications approach used for the preparation and presentation of the research project's outcomes**

Reporting the research:

Reporting research undertaken, appropriate use of a suitable referencing method including citation

Preparation of a final project report (including structure, professional format, research vocabulary)

Project oral presentation such as using short presentations to discuss the work with representative audiences (e.g., professional discussions) and conclusions

Project written presentation

Poster development and other equivalent methods.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the preliminary stages involved in the creation of an engineering/manufacturing research project		
P1 Produce a research project proposal that clearly defines a research question or hypothesis. **P2** Examine the key project objectives, the resulting goals, and rationale.	**M1** Analyse the project specification and identify any project risks.	**D1** Produce a comprehensive project proposal that evaluates and justifies the rationale for the research.
LO2 Examine the analytical techniques used to work on all stages of the project and strategies required to overcome the challenges involved in a research project		
P3 Conduct a literature review of published material, either in hard copy or electronically, that is relevant to your research project. **P4** Examine appropriate research methods and approaches to primary and secondary research.	**M2** Analyse the strategies used to overcome the challenges involved in the literature review stage. **M3** Discuss merits, limitations, and pitfalls of approaches to data collection and analysis.	**D2** Critically analyse literature sources utilised, data analysis conducted, and strategies to deal with challenges.

Pass	Merit	Distinction
LO3 Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering/manufacturing context		
P5 Reflect on the effectiveness and the impact the experience has had upon enhancing personal or group performance.	**M4** Evaluate the benefits from the findings of the research conducted, and the impact on CPD.	**D3** Critically evaluate how the research experience enhances personal or group performance within an engineering/ manufacturing context.
LO4 Explore the communications approach used for the preparation and presentation of the research project's outcomes		
P6 Explore the different types of communication approaches that can be used to present the research outcomes. **P7** Communicate research outcomes in a professional manner for the intended audience.	**M5** Evaluate how the communication approach meets research project outcomes and objectives.	**D4** Critically reflect how the audience for whom the research was conducted influenced the communication approach used for the preparation and presentation of the research project's outcomes.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Belegundu A.D. and Chandrupatla T.R. (2019) *Optimization Concepts and Applications in Engineering.* 3rd Ed. Cambridge University Press.

Breach M. (2008) *Dissertation Writing for Engineers and Scientists.* Student Edition. Pearson Education Limited.

Cassel K. W. (2021) *Matrix, Numerical, and Optimization Methods in Science and Engineering.* Cambridge University Press.

Jana A.K. (2023) *Numerical Methods in Engineering: Theory and Process Applications.* Cambridge University Press.

Vaughan G.D., and Smith I.M. (2006) *Numerical methods for engineers.* CRC Press.

KIRKUP L. (2019) *Experimental Methods for Science and Engineering Students: An Introduction to the Analysis and Presentation of Data.* 2nd Ed. Cambridge University Press.

Leong E.C., Lee-Hsia C.H. and Wee Ong K.K. (2015) *Guide to Research Projects for Engineering Students: Planning, Writing, and Presenting*. Apple Academic Press Inc.

Oberlender G.D. (2014) *Project Management for Engineering and Construction*. 3rd Ed. McGraw-Hill Education.

Qiu M., QIU H., and Zeng Y. (2022) *Research and Technical Writing for Science and Engineering.* CRC Press.

Thiel D.V. (2014) *Research Methods for Engineers.* Cambridge University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

American Journal of Engineering Research

Arabian Journal for Science & Engineering

Scientific Reports

Engineering Reports

Science Progress

Cell Reports Physical Science

Engineering Research Express

European Journal of Engineering and Technology Research

IETE journal of research

Indian Journal of Engineering

International Journal of Indian Research

International Journal of Engineering Research in Africa

International Journal of Engineering Research & Technology

Journal of Engineering in Industrial Research

Journal of Engineering Research

Journal of Engineering Research and Sciences (JENRS)

Journal of Engineering Research and Reports

London Journal of Engineering Research

The Journal of Engineering Research [TJER]

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 5002: Professional Engineering Management

Unit 5041: Engineering project.

Unit 5002: Professional Engineering Management

Unit Code: F/651/0809

Level: 5

Credits: 15

Introduction

Engineers are professionals who can design, develop, manufacture, construct, operate, and maintain the physical infrastructure and content of the world we live in. They do this by using their academic knowledge and practical experience, in a safe, effective, and sustainable manner, even when faced with a high degree of technical complexity.

The aim of this unit is to continue building up on the knowledge gained in *Unit 4004: Managing a Professional Engineering Project* or *Unit 4062 Professional Engineering Practice*, to provide students with the professional standards for engineers and to guide them on how to develop the range of employability skills needed by professional engineers.

Among the topics included in this unit are: engineering strategy and services delivery planning, the role of sustainability, Total Quality Management (TQM), engineering management tools, managing people, and becoming a professional engineer.

On successful completion of this unit, students will be able to construct a coherent engineering services delivery plan to meet the requirements of a sector-specific organisation or business. They will display a personal commitment to professional standards and obligations to society, the engineering/manufacturing profession, and the environment.

This unit is assessed by a Pearson-set theme. The project brief will be set by the centre, based on a theme provided by Pearson (this will change annually). The theme and chosen project within the theme will enable students to explore and examine a relevant and current topical aspect of professional engineering/manufacturing sector.

***Please refer to the accompanying Pearson-set The Guide and the Theme Release document for further support and guidance on the delivery of the Pearson-set unit.**

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate risk management theories and practices employed in engineering/manufacturing projects

LO2 Produce an engineering/manufacturing services delivery plan that meets the requirements of a sector-specific organisation

LO3 Develop effective leadership, individual and group communication skills

LO4 Demonstrate personal commitment to professional standards and obligations to society, the engineering profession, and the environment.

Essential Content

LO1 **Evaluate risk management theories and practices employed in engineering/manufacturing projects**

The engineering/manufacturing business environment:

Organisational structures and functional elements

Strategic planning and deployment

Engineering strategy and services delivery planning

The role of sustainability and environmental efficiency in decision making

Total Quality Management (TQM)

Logistics and supply chain management

Financial data, information, storage, and data management systems

New product development strategies

Legal obligations and corporate responsibility.

Risk evaluation in engineering/manufacturing projects:

Overview of risk analysis, assessment, and management

Key theories, methods, and applications (e.g., machinery, manufacturing, power plants, supply chains, etc.)

Case studies – example uses of Decision Tree Analysis, What If Analysis, Event Tree Analysis, Fault Tree Analysis

Risk governance, safety, data sources, risk-informed decision-making, standards (e.g. ISO 31000: Risk management), security, and life-cycle use of risk.

Engineering relationships:

The relationship between engineering and financial management, marketing, purchasing, quality assurance, and public relations.

LO2 **Produce an engineering/manufacturing services delivery plan that meets the requirements of a sector-specific organisation**

Management tools/software for engineering/manufacturing sector:

Problem analysis and decision-making, change management, performance management, product and process improvement, scheduling matrix, project management (including use of tools/techniques e.g. SWOT (strengths, weaknesses, opportunities, threats) analysis, stakeholder matrices, risk mapping, radar charts and summary risk profiles), and earned value analysis.

Services Delivery Plan:

Detailed task breakdown

Challenges–Planned and unforeseen

Internal and external influence

Impact on other services/users/stakeholders

Cost implications

Responsibilities.

LO3 **Develop effective leadership, individual, and group communication skills**

Managing people:

Describe the most effective leadership styles

Techniques to effectively manage teams (e.g., clear vision, systematic, transparent, delegation, collaboration remote working, etc.)

Individual/team CPD with opportunities for upskilling/reskilling (e.g., digital competencies and sustainability goals/frameworks) and ownership

Impact of effectively managing people

Motivation theories

Coaching and mentoring.

Steps to follow for leading effective meetings and delivering effective presentations:

Meeting management skills

Communication skills: Listening, non-verbal communication, clarity and brevity, friendliness, confidence, empathy, open-mindedness, respect, feedback, and picking the right medium

Communication with groups: Group expectations; communication formats (e.g. written reports, verbal, electronic, social media, data metrics); dealing with reactions and disagreements; allowing and encouraging participation; acting on agreed outcomes; negative communication; motivating disillusioned colleagues; persuasion and negotiation

Human error evaluation

Coaching and mentoring.

Workplace considerations:

Human factors (organisational, environmental, and job factors), influence and impact individual characteristics, performance, and behaviours in the workplace

Systematic and proactive approach to problem-solving

Safety-first culture, policies and procedures, and compliance with legislative and organisation health, safety, and environmental requirements

Equality and diversity: Ensuring work produced and the approach to work is inclusive and takes proper, account of equality of opportunity and the diverse nature of the population.

LO4 **Demonstrate personal commitment to professional standards and obligations to society, the engineering profession, and the environment**

Becoming a professional engineer:

Engineering social responsibility

Importance of being active and up to date with the engineering profession, new developments and discoveries

Methods of Continuing Professional Development (CPD). Work ethics: positive, professional, respectful, trusting, and ethical working relationships. Lead by example. Holistic stakeholder engagement. Ownership of professional development and up-to-date with subject/sector developments (e.g., digital competencies, sustainability goals/frameworks).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate risk management theories and practices employed in engineering/manufacturing projects		
P1 Discuss any two risk evaluation theories associated with the management of engineering/ manufacturing projects. **P2** Evaluate risk assessment methods and practices that impact the successful management of engineering/ manufacturing activities.	**M1** Analyse the application of risk management theories for a given engineering/ manufacturing context.	**D1** Critically evaluate the challenges encountered when meeting the requirements for successfully managing engineering activities, with justified recommendations to overcome these challenges.
LO2 Produce an engineering/manufacturing services delivery plan that meets the requirements of a sector-specific organisation		
P3 Produce an engineering services delivery plan, applying the appropriate sector-specific requirements. **P4** Determine the engineering management tools needed for designing an engineering/ manufacturing services delivery plan.	**M2** Evaluate how each step of the delivery plan developed meets the requirements of a sector-specific organisation.	**D2** Critically evaluate contingencies that might prevent the delivery plan from meeting the requirements of a sector-specific organisation.

Pass	Merit	Distinction
LO3 Develop effective leadership, individual and group communication skills		
P5 Develop the steps for effective persuasion and negotiation. **P6** Explain the steps for managing effective group meetings. **P7** Outline the steps to deliver an effective presentation.	**M3** Evaluate leadership styles and effective communication skills using specific examples in an organisational context.	**D3** Critically evaluate effective ways to coach and mentor disillusioned colleagues or a poorly performing team.
LO4 Demonstrate personal commitment to professional standards and obligations to society, the engineering profession, and the environment		
P8 Examine the context of social responsibility for scientists and engineers. **P9** Demonstrate the ways by which an engineer can engage in continuing professional development.	**M4** Summarise the engineering profession's ethical standards and patterns of behaviour.	**D4** Provide justifications as to why it is necessary to be active and up to date with the engineering profession's new developments and discoveries.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bahr N.J. (2015) *System Safety Engineering and Risk Assessment – A Practical Approach*. Second Edition. CRC Press

Burns, B. (2014) *Managing Change*. 6th Ed. Pearson.

Challender J. (2022) *Professional Ethics in Construction and Engineering.* Wiley.

Covello V.T. (2021) *Communicating in Risk, Crisis, and High Stress Situations: Evidence-Based Strategies and Practice*. Wiley.

Dearden, H. (2013) *Professional Engineering Practice: Reflections on the Role of the Professional Engineer.* CreateSpace Independent Publishing Platform.

El-Reedy M.A. (2021) *Offshore Projects and Engineering Management*. 1st Edition. Elsevier.

Karten, N. (2010) *Presentation Skills for Technical Professionals*. IT Governance Ltd.

Kerzner H. (2022) *Project Management: A Systems Approach to Planning, Scheduling, and Controlling.* 13th Edition, Wiley.

Kiran D.R. (2022) *Principles of Economics and Management for Manufacturing Engineering.* Elsevier.

Kong K. (2019) *Professional Discourse.* Cambridge University Press.

Lock, D. (2013) *Project Management*. 10th Ed. Routledge.

Muzio D., Sundeep A. and Kirkpatrick I. (2020) *Professional Occupations and Organizations.* Cambridge University Press.

Rausand M. and Stein Haugen S. (2020) *Risk Assessment: Theory, Methods, and Applications*. John Wiley & Sons, Inc.

Temple T.J. and Ladyman M.K. (2022) *Challenges in Risk Analysis for Science and Engineering*. IOP Publishing Ltd.

Wilbers S. (2022) *Persuasive Communication for Science and Technology Leaders: Writing and Speaking with Confidence*. Wiley.

Wright I. (2012) *Risk Evaluation (Engineering Design Book 1)*. Kindle Edition.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advanced Engineering Informatics

Advances in Engineering Software

Applications in Engineering Science

Control Engineering Practice

Cleaner Engineering and Technology

Engineering

Engineering Applications of Artificial Intelligence

Engineering Management

Engineering Management Journal

Frontiers of Engineering Management

IEEE Transactions on Engineering Management

Journal of Engineering and Technology Management

Journal of Management & Organization

Journal of Professional Issues in Engineering Education and Practice

Microelectronic Engineering

Probability in the Engineering and Information Sciences

Probabilistic Engineering Mechanics

Results in Engineering

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 5003: Advanced Mechanical Principles

Unit Code: K/651/0810

Level: 5

Credits: 15

Introduction

A mechanical engineer is required to have an advanced knowledge of most of the machinery used within the engineering industry, and should understand the physical laws that influence their operation.

The aim of this unit is to continue covering the topics discussed in *Unit 4008: Mechanical Principles* and other higher-level topics such as:

Poisson's Ratio and typical values of common materials; the relationship between the elastic constants such as Bulk Modulus, Modulus of Elasticity, Modulus of Rigidity; the relationship between bending moment, slope, and deflection in beams; calculating the slope and deflection for loaded beams using Macaulay's method; analysing the stresses in thin-walled pressure vessels; and stresses in thick-walled cylinders, flat and v-section belt drive theory.

On successful completion of this unit students will be able to have more advanced knowledge of mechanical principles including behavioural characteristics of materials subjected to complex loading, the strength of loaded beams and pressurised vessels, specifications of power transmission system elements, and operational constraints of dynamic systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine the behavioural characteristics of materials subjected to complex loading

LO2 Assess the strength of loaded beams and pressurised vessels

LO3 Analyse the specifications of power transmission system elements

LO4 Examine operational constraints of dynamic systems.

Essential Content

LO1 **Determine the behavioural characteristics of materials subjected to complex loading**

Characteristics of materials:

Definition of Poisson's Ratio and typical values of metals, plastics and composite materials

The relationship between the elastic constants such as Bulk Modulus, Modulus of Elasticity, Modulus of Rigidity and Poisson's Ratio

Characteristics of two-dimensional and three-dimensional loading

Calculation of volumetric strain and volume changes

Concept of principal stress and strain

Failure criteria for ductile and brittle materials

Use of problem-solving tools within the context such as Root Cause Analysis (RCA) Process Failure Modes Effects Analysis (PFMEA), Fishbone, and Practical Problem Solving (PPS) and Advanced Product Quality Planning (APQP).

LO2 **Assess the strength of loaded beams and pressurised vessels**

Strength:

The relationship between bending moment, slope and deflection in beams

Calculating the slope and deflection for loaded beams using Macaulay's method

Analysing the stresses in thin-walled pressure vessels and stresses in thick-walled cylinders

Use of computer simulations to model the behaviour of beams.

LO3 **Analyse the specifications of power transmission system elements**

Specifications:

Flat and v-section belt drive theory

Operation of friction clutches with uniform pressure and uniform wear theories

Bending and contact stress in geared systems

Principles of both epicyclic and differential gearing, and the torque required to accelerate these systems

Areas of failure when transmitting power mechanically.

LO4 **Examine operational constraints of dynamic systems**

Operational constraints:

Design of mechanical components to meet operating specifications, displacement and velocity

Operating principles of flywheels to store mechanical energy

Balancing of rotating mass systems

Single degree of freedom (DOF) free and damped vibration.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine the behavioural characteristics of materials subjected to complex loading		
P1 Discuss the relationship between the elastic constants. **P2** Illustrate the effects of two-dimensional and three-dimensional loading on the dimensions of a given material. **P3** Determine the volumetric strain and change in volume due to three-dimensional loading.	**M1** Assess the effects of volumetric thermal expansion and contraction on isotropic materials.	**D1** Critique the behavioural characteristics of materials subjected to complex loading.
LO2 Assess the strength of loaded beams and pressurised vessels		
P4 Evaluate the variation of slope and deflection along a simply supported beam. **P5** Assess the principal stresses that occur in a thin-walled cylindrical pressure vessel and a pressurised thick-walled cylinder.	**M2** Refine the selection of a suitable size universal beam from appropriate data tables which conforms to given design specifications for slope and deflection.	**D2** Justify the choice of a suitably sized universal beam, using appropriate computer software to model the application by explaining any assumptions that could affect the selection.

Pass	Merit	Distinction
LO3 Analyse the specifications of power transmission system elements		
P6 Discuss the initial tension requirements for the operation of a v-belt drive. **P7** Analyse the force requirements to engage a friction clutch in a mechanical system. **P8** Analyse the holding torque and power transmitted through epicyclic gear trains.	**M3** Critically analyse both the uniform wear and uniform pressure theories of friction clutches for their effectiveness in theoretical calculations.	**D3** Evaluate the conditions needed for an epicyclic gear train to become a differential, showing how a differential works in this application.
LO4 Examine operational constraints of dynamic systems		
P9 Examine the profiles of both radial plate and cylindrical cams that will achieve a specified motion. **P10** Determine the mass of a flywheel needed to keep a machine speed within specified limits. **P11** Investigate the balancing masses required to obtain dynamic equilibrium in a system.	**M4** Evaluate the effects of misalignment of shafts and the use of problem-solving tools to prevent problems from occurring.	**D4** Critically evaluate different choices of mechanical systems that induce specified motion, including the advantages and disadvantages of each application.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird J. and Ross C. (2020) *Mechanical Engineering Principles*. 4th Ed. Routledge.

Childs P.R.N. (2021) *Mechanical Design: Theory and Applications.* 3rd Ed. Butterworth-Heinemann.

Hibbeler R.C. (2020) *Engineering Mechanics: Dynamics and Statics.* SI Edition. 14th Ed. Pearson.

Juvinall R.C. and Marshek K.M. (2020) *Fundamentals of Machine Component Design.* 7th Ed. Wiley.

Tooley M. and Dingle L. (2020) *Engineering Science: For Foundation Degree and Higher National*. 2nd Ed. Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Applied Mechanics Reviews

Archive of Rational Mechanics and Analysis

Computer Methods in Applied Mechanics and Engineering

Frontiers in Mechanical Engineering

International Journal of Engineering Science

International Journal of Mechanical Sciences

Journal of Machine Design

Journal of Mechanical Engineering

Journal of Mechanical Science and Technology

Mechanics Based Design of Structures and Machines

Mechanical Engineering Journal

Links

This unit links to the following related units:

Unit 4008: Mechanical Principles.

Unit 5004: Computational Modelling in Virtual Engineering

Unit Code: L/651/0858

Level: 5

Credits: 15

Introduction

The work of an engineer increasingly involves the use of powerful software modelling tools (virtual modelling). These tools allow us to predict potential manufacturing difficulties, suggest how a product or component is likely to behave in service, and undertake rapid and low-cost design iteration and optimisation, to reduce costs, pre-empt failure and enhance performance.

This unit introduces students to the application of relevant Computer Aided Design (CAD) and analysis engineering tools in contemporary engineering. They will learn about standards, regulations, and legal compliance within the context of engineering.

Topics included in this unit are: dimensioning and tolerances, standardisation and regulatory compliance (BS, ASTM, ISO, etc.), material properties and selection, manufacturing processes, 2D, 3D, CAD, solid modelling, one-dimensional and multi-dimensional problems, meshing and boundary conditions, and the finite element and volume methods.

On successful completion of this unit students will learn about computational fluid dynamics (CFD) simulations, finite element models, faults in the application of simulation techniques and the modelling method and data accuracy.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering.

LO2 Develop finite element model(s) in order to find and solve potential structural or performance issues.

LO3 Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting.

LO4 Discuss faults in the application of simulation techniques to evaluate the modelling method and data accuracy.

Essential Content

LO1 **Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering**

Engineering design fundamentals:

Dimensioning and tolerances

Standardisation and regulatory compliance (BS, ASTM, ISO, etc.)

How to manufacture and what to manufacture:

Material properties and selection

Manufacturing processes: capability, cost issues and selection

Relevance of Industry 4.0 tools/trends in support of solving engineering problems and facilitate seamless systems integration.

Design tools:

2D and 3D CAD

Solid modelling

File types, export and compatibility

Case studies involving use of various computer-based models for Engineering problem solving.

Interpretation and presentation of results through a series of guided exercises:

Results obtained, comparison of data, benefits and limitations; exploit uses of databases, data formats and data analytics

Generalisation of provided information, recommendations on current and future applications

Use of documentation within the context e.g. job cards/build records, 2D and 3D drawing/models, bill of materials (BOM), cost analysis reports, compliance reports, standard operating instructions (SOIs), standard process instructions (SPIs), engineering query notifications (EQNs), drawing query notifications (DQNs).

LO2 **Develop finite element model(s) in order to find and solve potential structural or performance issues**

Fundamentals of FEM (Finite Element Modelling):

Meshing, nodes and element types

Types of boundary conditions

FEM and FEA; applications, advantages, and limitations.

Finite element formulation:

One-dimensional problems, Multi-dimensional problems, Beams.

Finite element method:

Define the problem: simplify an engineering problem into a problem that can be solved using FEA

Develop models: define material properties and boundary conditions; choose appropriate functions, formulate equations, solve equations, visualise and explain the results.

LO3 **Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting**

Fundamentals of CFD (Computational Fluid Dynamics):

CFD and the finite volume method background

Meshing and boundary conditions

Applications, advantages and limitations of CFD.

CFD simulation and analysis:

Apply CFD to simple design/aerodynamics problems: define the problem, provide initial boundary conditions for the problem, set-up a physical model, define material properties and operating conditions

Interpretation of CFD results

Examine the solution of CFD simulations using graphical and numerical tools; suggest and make revision of the models.

LO4 **Discuss faults in the application of simulation techniques to evaluate the modelling method and data accuracy**

Simulation results:

Extracting relevant information from simulation-based exercises

Interpretation and presentation of results of CFD simulations

Validation and verification of computational modelling

Discuss in groups industry case studies involving simulation techniques in the context of data accuracy and faults.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering		
P1 Explore the capabilities and limitations of any two computer-based models used within an industrial environment to solve problems in engineering.	**M1** Analyse the capabilities and limitations of a range of computer-based models. **M2** Analyse the processes and applications used in solving problems in engineering.	**D1** Evaluate the application of computer-based models to an industrial environment that would improve efficiency and problem-solving, with recommendations.
LO2 Develop finite element model(s) in order to find and solve potential structural or performance issues		
P2 Analyse the role of finite element analysis in modelling products and systems. **P3** Develop a finite element model to analyse a given practical example to solving potential structural or performance-based issues.	**M3** Critically analyse the finite element model that help to find and solve potential structural or performance-based issues.	**D2** Justify recommendations for recognising and solving potential structural or performance-based issues for a range of practical examples, supported by the outcomes of finite element product and systems models for a range of practical examples.

Pass	Merit	Distinction
LO3 Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting		
P4 Demonstrate the importance of CFD simulations to evaluate pressure and velocity distributions in the engineering setting. **P5** Perform CFD simulation to evaluate pressure and velocity distributions within an engineering setting.	**M4** Evaluate the application and limitations of CFD in an engineering context.	**D3** Provide supported and appropriate recommendations for improving efficiency and the generation of suitable meshes for CFD simulations.
LO4 Discuss faults in the application of simulation techniques to evaluate the modelling method and data accuracy		
P6 Discuss potential faults in the application of simulation techniques. **P7** Discuss the use of modelling methods and data accuracy in computer simulations.	**M5** Trace potential faults in the application of simulation techniques. **M6** Assess the results of modelling with respect to outcomes and data accuracy and make recommendations for improvements.	**D4** Critically evaluate the application of simulation techniques as part of the decision-making process in an engineering situation.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Chandrupatla T. and Belegundu A. (2021) *Introduction to finite elements in engineering.* Cambridge University Press.

Ciarlet P. and Luneville E. (2023) *The Finite Element Method: From Theory to Practice.* Wiley-ISTE.

Kurowski P.M. (2022) *Finite element analysis for design engineers.* SAE International.

Muftu S. (2022) *Finite Element Method: Physics and Solution Methods.* 1st Ed. Academic Press.

Okada H. and atluri S.N. (2020) *Computational and Experimental Simulations in Engineering: Proceedings of ICCES2019.* Springer Link.

Rao S.S. (2017) *The Finite Element Method in Engineering.* 6th Ed. Butterworth-Heinemann.

Tu J., Yeoh G.H., Liu C. and Tao Y. (2023) *Computational fluid dynamics: a practical approach.* Elsevier.

Volkov K. (2020) *Computational Models in Engineering.* IntechOpen.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Computational Engineering and Physical Modeling

Finite Elements in Analysis and Design

International Journal for Computational Methods in Engineering Science and Mechanics

Progress in Computational Fluid Dynamics

Novel Computational Modelling (Applied Engineering Journal)

Virtual Engineering Journals

Virtual Engineering New Finding Journal

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 5017: Advanced Manufacturing Technology.

Unit 5005: Further Thermodynamics

Unit Code: M/651/0859

Level: 5

Credits: 15

Introduction

From the refrigerators that we use in our homes to the colossal power stations that generate the electricity we use and provide power to industry, the significance that thermodynamics plays in the 21st century cannot be underestimated.

This unit aims to build on the techniques explored in *Unit 4013: Fundamentals of Thermodynamics and Heat Transfer*, to develop further students' skills in applied thermodynamics by investigating the relationships between theory and practice.

Among the topics included in this unit are: heat pumps and refrigeration, performance of air compressors, steam power plants, and gas turbines.

On successful completion of this unit, students will be able to learn about the performance and operation of heat pumps and refrigeration systems, the applications and efficiency of industrial compressors, the use of charts and/or tables to determine steam plant parameters and characteristics, and the operation of gas turbines and assess their efficiency.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate the performance and operation of heat pumps and refrigeration systems

LO2 Review the applications and efficiency of industrial compressors

LO3 Determine steam plant parameters and characteristics using charts and/or tables

LO4 Examine the operation of gas turbines and assess their efficiency.

Essential Content

LO1 **Evaluate the performance and operation of heat pumps and refrigeration systems**

Heat pumps and refrigeration:

Reversed heat engines: reversed Carnot and Rankine cycles

Second law of thermodynamics

Refrigeration tables and charts (p-h diagrams)

Coefficient of performance of heat pumps and refrigerators

Vapor compression refrigeration cycle

Refrigerant fluids: properties and environmental effects

Economics of heat pumps.

LO2 **Review the applications and efficiency of industrial compressors**

Performance of air compressors:

Theoretical and realistic cycles

Isothermal and adiabatic work

Volumetric efficiency

Intercoolers, dryers, and air receivers

Hazards and faults: safety consideration and associated legislation.

LO3 **Determine steam plant parameters and characteristics using charts and/or tables**

Steam power plant:

Use of tables and charts to analyse steam cycles

Circuit diagrams showing boiler, super heater, turbine, condenser, and feed pump

Theoretical and actual operation: Carnot and Rankine cycle

Efficiencies and improvements: sustainability and environmental efficiency considerations in decision-making.

LO4 **Examine the operation of gas turbines and assess their efficiency**

Gas turbines:

Single and double-shaft gas turbine operation

Property diagrams: Brayton (Joule) cycle

Intercooling, reheating, and regeneration

Combined heat and power plants

Self-starting and burner ignition continuation

Fuels and Combustion,

Theoretical and actual combustion

Enthalpy-of-formation, enthalpy of combustion, and heating value

Safety first culture and application within the context: use of health and safety policies, procedures and regulations, compliance, risk assessment and mitigation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the performance and operation of heat pumps and refrigeration systems		
P1 Using didactic sketches, evaluate the operating principles of both heat pumps and refrigeration systems. **P2** Use refrigeration tables and pressure/enthalpy charts to determine COP, heating effect, and refrigeration effect of reversed heat engines.	**M1** Assess the limiting factors that impact the economics of heat pumps. **M2** Illustrate the contradiction between refrigeration cycles and the second law of thermodynamics.	**D1** Conduct a cost–benefit analysis of the installation of a ground source heat pump on a smallholding to make valid recommendations for improvements.
LO2 Review the applications and efficiency of industrial compressors		
P3 Review the different types of industrial compressors and identify justifiable applications for each. **P4** Discuss compressor faults and potential hazards. **P5** Determine the volumetric efficiency of a reciprocating compressor.	**M3** Evaluate isothermal efficiency by calculating the isothermal and polytropic work of a reciprocating compressor.	**D2** Critically evaluate the volumetric efficiency formula for a reciprocating compressor.
LO3 Determine steam plant parameters and characteristics using charts and/or tables		
P6 Determine the need for superheated steam in a power-generating plant. **P7** Apply the use of charts and/or tables to establish overall steam plant efficiencies in power systems.	**M4** Justify why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world.	**D3** Critically evaluate the pragmatic modifications made to the basic Rankine cycle to improve the overall efficiency of steam generation power plants.
LO4 Examine the operation of gas turbines and assess their efficiency		
P8 Investigate the principles of operation of a gas turbine plant. **P9** Examine the efficiency of a gas turbine system.	**M5** Compare the actual plant and theoretical efficiencies in a single-shaft gas turbine system, accounting for any discrepancies found.	**D4** Evaluate the enthalpy of combustion, using enthalpy of formation for the gas turbines.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Assael M.J., Maitland G.C., Maskow T., Stockar U.V., Wakeham W.A. and Will S. (2022) *Commonly Asked Questions in Thermodynamics.* 2nd Ed. CRC Press.

Bejan A. (2016) *Advanced Engineering Thermodynamics.* John Wiley & Sons, Inc.

Borgnakke C. and Sonntag R. (2022) *Fundamental of Thermodynamics.* 10th Ed. Wiley.

Baskharone E. A. (2012) *Thermal Science: Essentials of Thermodynamics, Fluid Mechanics, and Heat Transfer.* McGraw Hill.

Cengel Y.A., Boles M.A. and Kanoglu M. (2019) *Thermodynamics: An Engineering Approach Si*. 9th Ed. McGraw Hill.

Dixon, S. L. and Hall C. (2013) *Fluid mechanics and thermodynamics of turbomachinery.* Butterworth-Heinemann.

Granet I., Alvarado J. and Bluestein M. (2021) *Thermodynamics and Heat Power.* 9th Ed. CRC Press.

Kleinstreuer C. (2021) *Essentials of Engineering Thermodynamics.* 1st Ed. McGraw-Hill.

Lloyd W. (Editor) (2023) *Handbook of Heat Transfer and Fluid Flow (Hardback).* Willford Press.

Murphy K. (Editor) (2023) *Engineering Thermodynamics: Simulation with Entropy (Hardback).* Clanrye International.

Potter M.C. and Somerton C.W. (2019) *Schaums Outline of Thermodynamics for Engineers.* 4th Ed. McGraw-Hill.

Rayner J. (2008) *Basic Engineering Thermodynamics*. 5th Ed. Pearson.

Trachenko K. (Author) (2023) *Theory of Liquids: From Excitations to Thermodynamics* (Hardback). Cambridge University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Applied Thermal Engineering

International Communications in Heat and Mass Transfer

International Journal of Heat and Mass Transfer

International Journal of Turbomachinery, Propulsion and Power

International Journal of Thermal Sciences

Thermodynamics: A Section of Entropy

Journal of Turbomachinery

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 5023: Thermofluids.

Unit 5006: Further Engineering Mathematics

Unit Code: **Y/651/0860**

Level: **5**

Credits: **15**

Introduction

The understanding of more advanced mathematics is important within an engineering and manufacturing sector curriculum to support and broaden abilities within the applied subjects at the core of all engineering programmes. Students are introduced to additional topics that will be relevant to them as they progress to the next level of their studies, advancing their knowledge of the underpinning mathematics gained in *Unit 4002: Engineering Mathematics*.

The unit will prepare students to analyse and model engineering/manufacturing situations using mathematical techniques. Among the topics included in this unit are: number theory, complex numbers, matrix theory, linear equations, numerical integration, numerical differentiation, and graphical representations of curves for estimation within an engineering/manufacturing context. Finally, students will expand their knowledge of calculus to discover how to model and solve engineering/manufacturing problems using first and second-order differential equations.

On successful completion of this unit, students will be able to use applications of number theory in practical engineering situations, solve systems of linear equations relevant to engineering/manufacturing applications using matrix methods, approximate solutions of contextualised examples with graphical and numerical methods, and review models of engineering and manufacturing systems using ordinary differential equations.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Use applications of number theory in practical engineering/manufacturing situations

LO2 Solve systems of linear equations relevant to engineering//manufacturing sector applications using matrix methods

LO3 Approximate solutions of contextualised examples with graphical and numerical methods

LO4 Review models of engineering/manufacturing systems using ordinary differential equations.

Essential Content

LO1 **Use applications of number theory in practical engineering/manufacturing situations**

Number theory:

Bases of a number (Denary, Binary, Octal, Duodecimal, Hexadecimal) and converting between bases

Types of numbers (Natural, Integer, Rational, Real, Complex)

The modulus, argument, and conjugate of complex numbers

Polar and exponential forms of complex numbers

The use of de Moivre's Theorem in engineering/manufacturing

Complex number applications e.g., electric circuit analysis, information, and energy control systems

Application of advanced numerical skills (Binary, dotted decimal notation) required to meet the defined specifications

Problem-solving and ensuring quality solutions to practical engineering/manufacturing situations relevant to the occupation/sector (e.g., operations, manufacturing, space, aeronautical, automation, electrical, electronics, mechanical, etc.); attention to detail and responsive to feedback; communication and presentation of solutions (including written, verbal, electronic format) to stakeholders, discussions, and negotiations.

LO2 **Solve systems of linear equations relevant to engineering/manufacturing applications using matrix methods**

Matrix methods:

Introduction to matrices and matrix notation

The process for addition, subtraction, and multiplication of matrices

Introducing the determinant of a matrix and calculating the determinant for a 2x2 and 3x3 matrix

Using the inverse of a square matrix to solve linear equations

Cramers Rule

Gaussian elimination to solve systems of linear equations (up to 3x3)

Eigenvalues and Eigenvectors.

LO3 **Approximate solutions of contextualised examples with graphical and numerical methods**

Graphical and numerical methods:

Standard curves of common functions, including quadratic, cubic, logarithm, and exponential curves

Systematic curve sketching knowing the equation of the curve

Using sketches to approximate solutions of equations

Numerical analysis using the bisection method and the Newton–Raphson method

Numerical integration using the mid-ordinate rule, the trapezium rule, and Simpson's rule

Examples of engineering scenarios using numerical methods for first-order and second-order differential equations; partial differential equations; homogeneous and non-homogeneous equations.

LO4 **Review models of engineering/manufacturing systems using ordinary differential equations**

Differential equations:

Formation and solutions of first-order differential equations (e.g., separation of variables)

Applications of first-order differential equations e.g., RC and RL electric circuits, Newton's laws of cooling, charge and discharge of electrical capacitors, and complex stresses and strains

Formation and solutions of second-order differential equations

Applications of second-order differential equations e.g., mass-spring-damper systems, information and energy control systems, heat transfer, automatic control systems and beam theory and RLC circuits

Introduction to Laplace transforms for solving linear ordinary differential equations

Applications involving Laplace transforms and inverse Laplace transforms. For example, electric circuit theory, load frequency control, harmonic vibrations of beams, reactor dynamics, and engine governors.

Continuous Professional Development (CPD) within the context:

Improve competencies in developing/using mathematical models of advanced engineering and manufacturing systems relevant to chosen occupation/sector through upskilling/reskilling opportunities (e.g., energy sustainability systems/models, climate change mathematical models for renewable technologies, advanced mathematics for Industry 4.0 technologies, applied mathematics for digitalisation, etc.).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Use applications of number theory in practical engineering/manufacturing situations		
P1 Use addition and multiplication methods for numbers that are expressed in different base systems. **P2** Solve engineering/manufacturing problems using complex number theory. **P3** Perform arithmetic operations using the polar and exponential forms of complex numbers.	**M1** Solve problems using de Moivre's Theorem.	**D1** Test the correctness of a trigonometric identity using de Moivre's Theorem.
LO2 Solve systems of linear equations relevant to engineering/manufacturing applications using matrix methods		
P4 Calculate the determinant of a set of given linear equations using a 3x3 matrix. **P5** Solve a system of three linear equations using Gaussian elimination.	**M2** Determine the solution to a set of given engineering linear equations using the Inverse Matrix Method for a 3x3 matrix.	**D2** Validate solutions for the given engineering linear equations using appropriate computer software.

Pass	Merit	Distinction
LO3 Approximate solutions of contextualised examples with graphical and numerical methods		
P6 Approximate solutions of sketched functions using a graphical estimation method. **P7** Calculate the roots of an equation using two different iterative techniques **P8** Determine the numerical integral of engineering functions using two different methods.	**M3** Solve engineering problems and formulate mathematical models using graphical and numerical integration.	**D3** Critically evaluate the use of numerical estimation methods, commenting on their applicability and the accuracy of the methods.
LO4 Review models of engineering/manufacturing systems using ordinary differential equations		
P9 Review and solve first-order differential equations related to engineering/ manufacturing systems. **P10** Formulate and solve second-order homogeneous and non-homogeneous differential equations related to engineering/manufacturing systems. **P11** Calculate solutions to linear ordinary differential equations using Laplace transforms.	**M4** Demonstrate how different models of engineering systems using first-order differential equations can be used to solve engineering/ manufacturing problems.	**D4** Critically evaluate first-order and second-order differential equations when generating the solutions to engineering/ manufacturing situations, using models of engineering systems.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Arfken G. B., Weber H. J., and harris F. E. (2011) *Mathematical methods for physicists: a comprehensive guide*. Academic press.

Bird J. (2021) *Higher Engineering Mathematics*. 9th Ed. Routledge.

Bird J. (2019) *Science and Mathematics for Engineering*. 6th Ed. Routledge.

Botelho F.S. (2021) *Functional Analysis, Calculus of Variations and Numerical Methods for Models in Physics and Engineering*. 1st Edition. CRC Press.

Chapra S. (2022) *Applied Numerical Methods with MATLAB for Engineers and Scientists.* 5th Edition. McGraw-Hill.

Chapra S. and Clough D. (2021) *Applied Numerical Methods with Python for Engineers and Scientists.* 1st Edition. McGraw-Hill.

Chapra S. and Canale R. (2020) *Numerical Methods for Engineers.* 8th Edition. McGraw-Hill.

Croft A., Davison R., Hargreaves M., and Flint J. (2017) *Engineering Mathematics.* 5th edition. Pearson Education.

Duffy D.G (2022) *Advanced Engineering Mathematics: A Second Course with MatLab.* 1st Edition. CRC Press.

Glyn J. and Dyke P. (2020) *Modern Engineering Mathematics.* 6th edition. Pearson.

Islam N., Singh S.B., Ranjan P., and Haghi A.K. (2021) *Mathematics Applied to Engineering in Action: Advanced Theories, Methods, and Models.* 1st Edition. CRC Press.

Made Easy Editorial Board (2022) *Engineering Mathematics for GATE 2023 and ESE 2023* (Prelims) – *Theory and Previous Year Solved Papers.* India: Made EASY Publications Pvt Ltd.

Ram M. (2021) *Recent Advances in Mathematics for Engineering.* CRC Press.

Teodorescu P., Stanescu N., and Pandrea N. (2013) *Numerical Analysis with Applications in Mechanics and Engineering.* Wiley-IEEE Press.

Ram M. (2020) *Mathematics in Engineering Sciences: Novel Theories, Technologies, and Applications.* 1st Edition. CRC Press.

Vick B. (2020) *Applied Engineering Mathematics.* CRC Press.

Singh K. (2011) *Engineering Mathematics Trough Applications*. Basingstoke, Palgrave Macmillan.

Stroud K.A. and Booth D.J. (2013) *Engineering Mathematics*. 7th Ed: Basingstoke, Palgrave Macmillan.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Annals of Mathematics

Computational Geometry

The Quarterly Journal of Mathematics

Journal of Geometry and Physics

Communications on Pure and Applied Mathematics

International Journal of Engineering Mathematics

Journal of Engineering Mathematics

Journal of Mathematical Physics

Journal of Computational and Engineering Mathematics

Links

This unit links to the following related unit:
Unit 4002: Engineering Mathematics

Unit 5007: Commercial Programming Software

Unit Code: A/651/0861

Level: 5

Credits: 15

Introduction

The use of Computer Aided Design (CAD) and simulation in the electronic and electrical engineering industry is ever growing. Commercial software packages enable an engineer to design, simulate, model and predict the outcome of a design before a product has been made. This enables time and cost savings in the development of a product whilst enabling the engineer to further develop their design.

The aim of this unit is to introduce students to the availability and use of commercial software packages within electronics engineering, including design, simulation, simple microprocessor programming and evaluation of the tools available.

On successful completion of this unit students will be able to research a range of software tools or applications to support engineering functions related to electronics, consider how a software package can be used to simulate the behaviour of an electronic circuits function, explain how to programme a microprocessor-based device to achieve a specified outcome/task, evaluate a specific electronics software tool/application, describe the types of commercial software available, compare the differences between a software simulation and a real-world circuit, and write simple commands to a microcontroller.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Research a range of software application tools to determine how they can support electronic engineering functions effectively

LO2 Explain how a software package can be used to simulate the behaviour of an electronic circuit function and compare the results to real components and circuits

LO3 Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software

LO4 Evaluate an electronics software application tool to report on its ability to replicate the real world and the resource savings this can bring to an organisation.

Essential Content

LO1 **Research a range of software application tools to determine how they can support electronic engineering functions effectively**

Exposition of computer packages or applications:

Circuit design, simulation, testing and analysis

Printed circuit board layouts

Electronic design automation (EDA or ECAD)

Microcontroller programming, such as Programmable Intelligent Computers (PICs). Microcontroller function simulation, monitoring and testing.

LO2 **Explain how a software package can be used to simulate the behaviour of an electronic circuit function and compare the results to real components or circuits**

Application of an industrial computer-aided design package:

Simulation and analysis of electronic circuits.

PCB design:

Creation of schematic netlists of a given design and transfer to a PCB layout to make design created using computer-based tools.

Build:

Component identification and handling

Develop soldering skills to be able to populate a printed circuit board.

Test and comparison:

Application of test equipment to measure voltage, current and resistance
Systematic test, commission and fault finding methods

Compare simulated values with tested values, comparison criteria to include; function, behaviour, accuracy, response times and errors.

LO3 **Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software**

Introduction to microprocessors:

Introduction to: common languages, compilers and simulators in-circuit debugging

Simple programming for exercises:

Digital inputs, simple user feedback

Simulation and debugging

Motor, relay and sound outputs

Communication.

LO4 **Review an electronics software application tool to report on its ability to replicate the real world and the resource savings this can bring to an organisation.**

Software application:

Software applications with specific industry examples incorporating ease of use, functions available, performance, reliability, quality and costs

Possible limiting factors in software systems, based on previous work undertaken in the unit

Current trends in simulation, testing and microprocessor development.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Research a range of software application tools to determine how they can support electronic engineering functions effectively		
P1 Examine the functions of commercial programming software. **P2** Discuss the categories of commercial electrical and electronic software.	**M1** Analyse the effectiveness of a range of commercial software in supporting electronic engineering functions.	**D1** Evaluate the functions and benefits of a range of commercial software used in developing electrical engineering.
LO2 Explain how a software package can be used to simulate the behaviour of an electronic circuit function and compare the results to real components or circuits		
P3 Design a simple PCB layout using a software package. **P4** Investigate and compare results produced in simulation to develop an analysis with the physical build.	**M2** Design a complex PCB layout with a good level of optimisation using a software package. **M3** Evaluate functionality of simulation to show considered comparisons between testing and simulation.	**D2** Critically evaluate the functionality of simulation in comparison with real components, using a complex PCB layout.

Pass	Merit	Distinction
LO3 Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software		
P5 Programme a microprocessor-based device to produce working code using appropriate software. **P6** Test and review code used through simulation and in the hardware.	**M4** Make improvements to given examples to produce complex working code. **M5** Evaluate code through simulation and in the hardware, demonstrating good competence of the software.	**D3** Critically evaluate the functionality of simulation by noting variations between testing and simulation.
LO4 Review an electronics software application tool to report on its ability to replicate the real world and the resource savings this can bring to an organisation.		
P7 Evaluate an electronics software application and its ability to replicate the real world, supported by industry specific examples and illustrating the resource savings implications offered by this approach.	**M6** Analyse an electronics software application and its ability to replicate the real world, supported by specific industry examples and illustrating the resource savings implications this has.	**D4** Critically analyse current and emerging applications of commercial software, with clear application to industry examples, identifying trends and recognising technical and economic factors that influence developments.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Blum J. (2013) *Exploring Arduino*. Wiley.

Cilingiroglu U. (2019) *Analog Integrated Circuit Design by Simulation: Techniques, Tools, and Methods.* McGraw Hill.

Petruzzellis T. (2005) *Build your own electronics workshop*. McGraw-Hill.

Richardson M. and Wallace S. (2013) *Getting started with Raspberry Pi*. 1st Ed. Maker Media Inc.

Robbins A. and Miller W.C. (2013) *Circuit analysis: theory and practice*. 5th Ed. International Ed. Clifton Park, N.Y.: Delmar.

Websites

https://www.circuitlab.com/	Circuit Lab Online schematic editor and circuit simulator (Training)

Links

This unit links to the following related units:

Unit 4023: Computer Aided Design and Manufacture (CAD/CAM)

Unit 5004: Virtual Engineering

Unit 5008: Distributed Control Systems.

Unit 5008: Distributed Control Systems

Unit Code: D/651/0862

Level: 5

Credits: 15

Introduction

With increased complexity and greater emphasis on cost control and environmental issues, the efficient control of manufacture and processing plant becomes ever more important. While small and medium scale industries require Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) technologies, large scale applications require Distributed Control Systems (DCS).

This unit introduces students to the applications of Distributed Control Systems in industrial measurements and control engineering, the different types of industrial networking used in control and instrumentation, the analysis of the performance of a given control system, and how to suggest appropriate solutions using a variety of possible methods.

On successful completion of this unit students will be able to explain the impact of automated systems in modern control processes, explain the basic concepts, architecture, operation and communication of distributed control systems, identify appropriate techniques to specify and implement a simple DCS and develop programmes to use machine interfaces to monitor and control the behaviour of a complex system.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explore the impact of automated systems in modern control processes

LO2 Evaluate the basic concepts, architecture, operation and communication of Distributed Control Systems

LO3 Suggest appropriate techniques to specify and implement a simple Distributed Control System

LO4 Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system.

Essential Content

LO1 Explore the impact of automated systems in modern control processes

Modern control processes:

Introduction to computer-based control systems and typical distributed control systems

An overview of DCS and SCADA systems

Fundamentals of PLC

Comparison of DCS, SCADA and PLCs

Selection and justification of control strategies.

LO2 Evaluate the basic concepts, architecture, operation and communication of Distributed Control Systems

Distributed Control Systems:

Evolution and description of commercial DCS, DCS elements

Basic DCS controller configuration

Introduction to basic communication principles and protocol for DCS, PLC and SCADA

Hierarchical systems and distributed systems

Introduction to simulation models and packages.

LO3 Suggest appropriate techniques to specify and implement a simple Distributed Control System

Techniques:

Introduction to programmable controllers, programming of PLC and DCS systems

Operator interface

Alarm system management for DCS systems

Distributed Control System reporting

Configuration of hardware and software of PLC and DCS

Programmable controller interfacing and troubleshooting

Configuration of a typical DCS control using typical plant problems.

LO4 **Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system.**

Behaviours:

Computation of control systems

Control and supervision of Distributed Control Systems

Human Machine Interfaces (HMIs) and alarms

Network communication standards

Application of field interfaces and networks

Application of diagnostic and maintenance consideration

Project implementation phases and life cycle

Overview of future trends (e.g. digital control, intelligent systems and virtual instruments).

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explore the impact of automated systems in modern control processes</td><td rowspan="2">D1 Critically evaluate and justify the selection of control strategies and their function against the specifications of a DCS.</td></tr>
<tr><td>P1 Discuss the application of DCS, SCADA and PLC, and their respective fields of application.

P2 Investigate the component parts and their respective functions, in a modern control process.

P3 Review the main building blocks (layout), communication paths and signal level(s) of a DCS.</td><td>M1 Evaluate the use of DCS from field devices to commercial data processing.

M2 Illustrate the control modes, structures, and diagnostic methods used in controllers.</td></tr>
<tr><td colspan="2">LO2 Evaluate the basic concepts, architecture, operation and communication of Distributed Control Systems</td><td rowspan="2">D2 Critically evaluate the performance of the operator interface in a DCS and its associated hardware.</td></tr>
<tr><td>P4 Evaluate the concept, architecture, operation and communication of DCS, SCADA and PLC in their respective applications.

P5 Review the hierarchical systems in DCS.

P6 Assess the use of Local Area Network, field bus types, and protocols.</td><td>M3 Critique the input output interface, fieldbus protocols and physical layers of a distributed control system.

M4 Critically examine the application of local area network communication and network types to distributed control systems.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Suggest appropriate techniques to specify and implement a simple Distributed Control System		
P7 Review the application and implementation of the DCS systems. **P8** Determine appropriate techniques for the application of DCS in different environments. **P9** Design and implement a simple DCS to satisfy predefined parameters.	**M5** Develop a high level programme for a typical plant problem. **M6** Explore the hardware and software configuration of a typical plant problem, making use of various operator display configurations.	**D3** Analyse the interfacing, structure and performance of a good alarm system.
LO4 Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system.		
P10 Explain the importance of the control principles and supervision of a DCS. **P11** Apply HMI to different process control applications and understand the alarm reporting. **P12** Demonstrate the role of the operator interface, associated hardware, diagnostics and maintenance for a DCS.	**M7** Show how the configuration control procedures ensure data integrity. **M8** Explore the requirements for in-built diagnostics and maintenance diagnostic routines.	**D4** Analyse and justify the choice of hardware, software and communication systems and strategy in terms of architecture, system requirements, system integration and toolkits available.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bailey, D. and Wright, E. (2003) *Practical SCADA for Industry*. Newnes.

Bolton W. (2021) *Instrumentation and Control Systems.* 3rd Ed. Elsevier.

Boyer, S. (2004) *SCADA-Supervisory Control and Data Acquisition System*.
3rd Ed. The Automation Systems and Automation Society (ISA) publication.

Ghosh A. (2015) *Distributed Systems: An Algorithmic Approach*. 2nd Ed. CRC Press.

Sharma, K. (2011) *Overview of Industrial Process Automation*. Elsevier.

Links

This unit links to the following related units:

Unit 5007: Commercial Programming Software

Unit 5021: Further Control Systems Engineering.

Unit 5009: Further Programmable Logic Controllers (PLCs)

Unit Code: F/651/0863

Level: 5

Credits: 15

Introduction

Programmable Logic Controllers (PLCs) were invented by the American Richard ('Dick') Morley in 1969, to be used in the manufacture of cars. Prior to that date production lines had been controlled by a mass of hard-wired relays. Using programmable devices in their place meant that changes in production could be implemented much faster without the need to rewire control circuits.

The aim of this unit is to further develop students' skills in the use of PLCs and their specific applications within engineering and manufacturing. Among the topics included in this unit are: device interface methods, PLC signal processing and communications with other devices, PLC programming methodology and alternative programmable control devices.

On successful completion of this unit students will be able to research the design, selection and use of PLCs as part of a larger system, programme a PLC to solve an industrial process problem for a given application and illustrate the alternative strategies for using other available types of programmable control devices.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Discuss the selection of a specific PLC for a given industrial application

LO2 Evaluate how PLCs exchange information and process signals with other devices

LO3 Design a PLC programme to solve an industrial process problem for a given application

LO4 Analyse alternative strategies using other types of programmable control devices in industrial applications.

Essential Content

LO1 **Discuss the selection of a specific PLC for a given industrial application**

PLC selection:

Common PLC industrial applications

Different PLC types, their features and PLC manufacturers

External input and output devices: analogue and digital

PLC operational characteristics: speed, current, voltages, memory

Alternative PLC modules available: Relay, Triac, Transistor, Analogue to Digital.

LO2 **Evaluate how PLCs exchange information and process signals with other devices**

PLC signal processing and communications with other devices:

Communication links and standards

Networked bus systems

Supervisory Control and Data Acquisition (SCADA) systems and Human Machine Interfaces (HMIs).

LO3 **Design a PLC programme to solve an industrial process problem for a given application**

PLC programming methodology:

Fundamentals of logic–ladder diagrams and other programming structures

PLC programming methods used of PLCs in accordance with IEC 61131

Logic functions: AND, OR, NOT, EXOR

Number systems used by PLCs: Binary, Hexadecimal, Octal, BCD

System input and output allocation data

Advanced functions: registers, Analogue to Digital (AtoD), performing calculations, high-speed counters and timers

Program test and debug software functions

Fault-finding of systems using PLC software remotely

Software toolbox elements

Virtual PLC simulations.

LO4 **Analyse alternative strategies for using other types of programmable control devices in industrial applications.**

Alternative programmable control devices:

Programmable Logic Device (PLD)

Peripheral Interface Controller (PIC)

Microcontrollers

Industrial computers.

Programmable device interface methods:

Relays and solid state relays

Opto couplers

Opto isolators

Motor driver interface integrated circuits.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss the selection of a specific PLC for a given industrial application		**D1** Evaluate and justify the selection of a specific PLC for an industrial application.
P1 Investigate the key industrial application characteristics of a given industrial application. **P2** Compare the operational features and characteristics of PLCs from several manufacturers.	**M1** Justify the choice of a specific PLC suitable for a given industrial application.	
LO2 Evaluate how PLCs exchange information and process signals with other devices		**D2** Provide a justified and valid rationale for the convergence of PLCs/HMIs and SCADA control systems.
P3 Illustrate the main differences between communication links and standards used within PLC systems. **P4** Review the advantages of using networked bus PLC systems.	**M2** Show how PLCs in industry integrate with HMIs and SCADA. **M3** Evaluate the use of SCADA and HMIs in industry.	
LO3 Design a PLC programme to solve an industrial process problem for a given application		**D3** Critically evaluate a PLC programme used to solve an industrial application problem.
P5 Design a PLC programme to solve an industrial application problem. **P6** Demonstrate the use of PLC programming and simulation software in a given application.	**M4** Demonstrate the use of test and debug software to correct PLC program faults. **M5** Explore the practical uses of PLC advanced functions.	
LO4 Analyse alternative strategies for using other types of programmable control devices in industrial applications.		**D4** Critically evaluate the selection of an alternative programmable device in a given application.
P7 Review the different types of programmable control devices available. **P8** Examine an industrial application to determine the required characteristics of a control device.	**M6** Review the problems faced by using alternative devices in an industrial environment.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bolton, W. (2015) *Programmable Logic Controllers*. 5th Ed. Newes.

Kamel, K. and Kamel, E. (2013) *Programmable Logic Controllers: Industrial Control*. McGraw-Hill Education.

Morton, J. (2005) *The PIC Microcontroller: Your Personal Introductory Course*. 3rd Ed. Newnes.

Perez, E. (2012) *Introduction to PLCs: A beginner's guide to Programmable Logic Controllers*. Elvin Perez Adrover.

Petruzella F. (2023) *Programmable Logic Controllers*. 6th Ed. McGraw Hill.

Rehg A. R. and SARTOR J. G. (2014) *Programmable Logic Controllers.* 2nd Ed. Pearson.

Stewart G. R. (2021) *Plc Programming for Beginners*. SIEMENS.

Websites

http://www.seipub.org/	Science and Engineering Publishing Company International Journal of Information and Computer Science (Journal)
http://www.airccse.org/	AIRCC Publishing Corporation International Journal of Computer Science, Engineering and Information Technology (IJCSEIT) (Journal)

Links

This unit links to the following related units:

Unit 4006: Mechatronics

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 5007: Commercial Programming Software.

Unit 5010: Further Electrical Machines and Drives

Unit Code: H/651/0864

Level: 5

Credits: 15

Introduction

Electric machines are used to convert electrical power to mechanical power or vice-versa. They are an indispensable part of engineering processes and are the workhorse in both commercial and industrial applications.

The aim of this unit is to continue developing the skills in the use and application of electrical machines, particularly direct current (DC) and alternating current (AC) drives.

Among the topics included in this unit are: an introduction to electrical machines and drives, and their characteristics, starting and braking, loading conditions, ratings, and their control.

On successful completion of this unit students will be able to learn about the operation of different motors used in industry, different types of industrial drives used in various disciplines, assessing the importance of electrical machines and their drives for a given industrial application, and analysing their performances and suggest appropriate solutions using a variety of possible methods.

Prior learning: It is recommended to complete *Unit 4021 Electrical Machines* before studying this unit.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Synthesise knowledge and skills on the principles of operation and the characteristics of electrical machines and their industrial applications

LO2 Examine the fundamentals of power electronics converters

LO3 Analyse the operation and characteristics of DC drives and their industrial applications

LO4 Analyse the operation and characteristics of AC drives and their industrial applications

Essential Content

LO1 **Synthesise knowledge and skills on the principles of operation and the characteristics of electrical machines and their industrial applications**

Principles of operation and characteristics of electrical machines and their industrial applications:

Electrical machines, concepts of electrical machines and their classification

Principles of operation of DC machines and their characteristics

Principles of operation of three-phase induction machines and their characteristics

Principles of operation of synchronous machines and their characteristics

Introduction to special machines

Four-quadrant torque-speed operation, inertia, and friction characteristic of electrical machines.

Simulation using Matlab/Simulink or similar commercially available software

Methods and practices for operations and control: Administrative controls; operational controls; geometry, location, access; hazards and control measures in practice: commissioning, decommissioning, monitoring and repair of electrical machines; storage and transport; sustainability factors in industrial applications; associated documentation control processes (including access, authorisation, location, format) and standard operating procedures (SoPs); relevant use of data collection systems, data input/output formats within the context of industrial use of electrical machines.

Electrical machines and Industry 4.0: Use and benefits from increased connectivity, performance optimisation, integration and impact on organisations. Example applications such as data driven condition monitoring and multidrive systems.

LO2 **Examine the fundamentals of power electronics converters**

Fundamentals of power electronics converters used in power processing units for electric drives:

Electronic switches (transistors); MOSFETs, IGBTs and how they are driven including practical considerations

Concepts of electrical drives and their classification

DC to DC converters, AC to DC converters (Rectifiers), DC to AC converters (Inverters), AC to AC converters (Cyclo-converters)

Simulation using Matlab/Simulink or similar commercially available software.

LO3 **Analyse the operation and characteristics of DC drives and their industrial applications**

Operation and characteristics of DC drives and their industrial applications:

DC drives and their application to emerging areas such as smart grids and renewable energy sources

Operating modes of DC drives; single-phase drives, three-phase drives, Pulse Width Modulation (PWM), two/four quadrant operation drives

Application; closed loop control of DC drives

Simulation using Matlab/Simulink or similar commercially available software

Practical experience in using equipment, where available

Safety first culture in industrial application design − health and safety policies, procedures and regulations, compliance, individual/team responsibilities, risk assessment and risk mitigation.

LO4 **Analyse the operation and characteristics of AC drives and their industrial applications**

Operation and characteristics of AC drives and their industrial applications:

AC drives and their industrial applications such as process control, smart grids and renewable energy sources

Induction motor drives: voltage, and frequency control (V/f with RL compensation), and closed loop speed control

Synchronous motor drives: closed loop speed control (Field Oriented Control, FOC) of synchronous motor drives

Simulation using Matlab/Simulink or similar commercially available software

Practical experience in using equipment, where available.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Synthesise knowledge and skills on the principles of operation and the characteristics of electrical machines and their industrial applications		
P1 Evaluate different types of electrical machines and their industrial applications. **P2** Illustrate the principle of operation of electrical machines with the aid of circuit diagrams and waveforms. **P3** Synthesise knowledge and skills on the construction, operation and characteristics of a given electrical machine.	**M1** Utilise Matlab and Simulink or similar software for modelling and simulation of a given electrical machine. **M2** Analyse the characteristics of a given electrical machine from its equivalent circuits.	**D1** Critically evaluate the performance of a given electrical machine for a specific application using Matlab, Simulink or similar software.
LO2 Examine the fundamentals of power electronics converters		
P4 Illustrate, with the aid of a circuit diagram and waveforms, the operation of a MOSFET half-bridge switch. **P5** Illustrate, with the aid of a circuit diagram and waveforms, the operation of a full-wave rectifier with smoothing. **P6** Examine with the aid of a circuit diagram, how an H-bridge converts DC to AC.	**M3** Demonstrate how Matlab and Simulink (or similar software) are used for modelling and simulation of a MOSFET half-bridge switch. **M4** Evaluate the key performance characteristics of a MOSFET half-bridge switch.	**D2** Critically evaluate the performance of a MOSFET half-bridge DC/AC converter using Matlab/Simulink software, using different MOSFETs.

Pass	Merit	Distinction
LO3 Analyse the operation and characteristics of DC drives and their industrial applications		**D3** Critically analyse the impact of a given DC drive on the operation and performance of a specific industrial process control system.
P7 Discuss the operating modes of DC drives and control parameters. **P8** Analyse the importance of DC drives in industrial applications. **P9** Conceptualise with the aid of diagrams how an H-bridge can be used to drive a DC machine at different speeds and directions. **P10** Illustrate, with the aid of diagrams the implementation of closed loop control of DC drives.	**M5** Develop an open loop block diagram (using Matlab Simulink or similar software) of a DC motor and derive the relationship between the input and the output of the system. **M6** Investigate the parameters influencing the output characteristics of a DC machine, driven by an H-Bridge when load is applied.	
LO4 Analyse the operation and characteristics of AC drives and their industrial applications		**D4** Critically analyse the impact of a given AC drive on the operation and performance of a specific industrial process control system.
P11 Analyse the operating modes of AC drives, their control parameters, and their importance in industrial applications. **P12** Illustrate, with the aid of circuit diagrams and waveforms, the principles of operation of three-phase AC drives. **P13** Propose, with the aid of diagrams, how an H-Bridge can be used to drive a single-phase AC machine.	**M7** Develop an open loop block diagram of an induction motor (using Matlab Simulink or similar software) and derive the relationship between the input and the output of the system. **M8** Investigate how AC drive circuits are used to control the speed of induction and synchronous motors.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Alassouli, H.M. (2021) *Lecture Notes for Electrical Machines Course*. Self-published.

Bose B.K. (2001) *Modern Power Electronics and AC Drives Hardcover*. Printice Hall.

Boldea I. and Tutelea L.N. (2021) *Electrical Machines: Steady State and Performance with MATLAB*. 2nd Ed. CRC Press.

Boldea I. and tutelea L.N. (2021) *Electrical Machines: Two Volume Se*t. 2nd Ed. CRC Press.

El-Sharkawi M.A. (2018) *Fundamentals of electric drives*. 2nd Ed., CL Engineering.

Fucha E.F. and Masoum M.A.S. (2023) *Power Quality in Power Systems, Electrical Machines, and Power-Electronic Drives*. 3rd Ed. Academic Press

Franchi C.M. (2022) *Electrical Machine Drives – Fundamental Basics and Practice*. CRC Press.

Gieras J.F. (2020) *Electrical Machines: Fundamentals of Electromechanical Energy Conversion*. CRC Press.

Hughes, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications.* 4th Ed. Newnes.

Rashid M.H. (2012) *Power Electronics: Circuits, Devices and Applications*. 4th Ed. Prentice Hall.

Rashid, M.H. (2001) *Power Electronics Handbooks*. 1st Ed. Academic Press.

Wildi T. (2014) *Electrical Machines, Drives and Power Systems*. 6th Ed. Pearson New International Edition.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

CES Transactions on Electrical Machines and Systems

Electrical Machines and Control 1007-449X

Electrical Machines and Drives – A Section of Machines

Electrical Machines and Electromechanics

Electrical Machines & Power Systems

Fundamentals of Electrical Drives

International Journal of Electrical Machines and Drives

International Journal of Electrical Power and Energy Systems

Journal of Electrical Engineering and Technology

Modern Electrical Drives: Trends, Problems, and Challenges

Links

This unit links to the following related units:

Unit 4021: Electrical Machines.

Unit 5011: Industrial Power, Electronics and Storage

Unit Code: J/651/0865

Level: 5

Credits: 15

Introduction

This unit presents a wide-ranging introduction to the field of existing and renewable energy systems. There are many alternative sources of energy (some 'green') which can be converted to an electrical form, providing energy for transport, heat/cooling, and lighting, as well as energy for various industrial processes and applications.

Power electronic converters are an essential component of renewable and distributed energy sources, including wind turbines, photovoltaics, marine energy systems and energy storage systems. It is necessary to gain a clear understanding of, and be able to examine, the technical implications of providing sustainable electrical energy to meet the energy demand of the future.

The unit will also explore the potential impacts of climate change and why more, and different forms of sustainable energy sources are required together with the need for energy efficiency measures.

On successful completion of this unit, students will be able to learn about the technological concepts behind providing a sustainable electrical energy supply for the future, the fundamental technical and economic processes, and drivers at play in the electrical power industry and how they affect the selection and use of energy sources.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate the energy demand to determine the technology and methods of energy production

LO2 Explore current energy efficiency measures, technologies, and policies specific to the building and transportation sectors

LO3 Analyse the control techniques of power electronics for renewable energy systems

LO4 Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid.

Essential Content

LO1 **Evaluate the energy demand to determine the technology and methods of energy production**

Energy demand:

Historical energy production, energy consumption, environmental aspects and global warming

The need for energy systems and global energy demand over the short to long term

Environmental effects associated with energy generation and consumption

Practicality, benefits, drawbacks, and effectiveness of renewable energy sources

Overview of non-renewable and renewable energy technologies (wind, solar, bio, hydro, geothermal) and the associated costs

Future energy trends, scenarios, and sustainable energy sources.

LO2 **Explore current energy efficiency measures, technologies, and policies specific to the building and transportation sectors**

Energy auditing, management, costs, requirements, bench marking and optimisation:

Energy management, planning, monitoring, policy, ecology, and environment.

Energy and buildings:

Overview of the significance of energy use and energy processes

Internal and external factors on energy use and the attributes of the factors

Sustainable buildings, Status of energy use in buildings and estimation of energy use in a building

Standards for thermal performance of building envelope and evaluation of the overall thermal transfer

Measures and technologies to improve energy efficiency in buildings,
SWOT analysis.

Energy and electric vehicles:

Electrical vehicle configurations, requirements, and circuit topology; full electric and plug in hybrid vehicles

Policies, charging infrastructure, grid implications, measures, and technologies to support more sustainable transportation, SWOT analysis

Use of MATLAB/Simulink or alternative appropriate software to model, simulate and analyse the energy efficiency of a typical standard house or electric vehicle.

LO3 **Analyse the control techniques of power electronics for renewable energy systems**

Control techniques:

Environmental aspects of electrical energy conversion using power electronics

Introduce design criteria of power converters for renewable energy applications

Analyse and comprehend the various operating modes of wind electrical generators and solar energy systems

Introduce the industrial application of power converters, namely AC to DC, DC to DC and AC to AC converters for renewable energy systems

Explain the recent advancements in power systems using the power electronic systems. Introduction to basic analysis and operation techniques on power electronic systems

Functional analysis of power converters' main topologies

Use of MATLAB/Simulink to model, simulate and analyse the dynamic behaviour of a simple renewable energy system.

LO4 **Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid**

Impact of renewable resources:

Safe and secure operation of a simple power system

Standalone and grid connected renewable energy systems

Introduction to smart grid, features, functions, architectures, distributed generation, grid integration and implications. Grid interactive systems, grid tied systems, inverters, and application of its devices

Smart homes, power management, smart grid, intelligent/smart metering

Communication technologies and power electronics modules for smart grid network, importance of power electronics in smart grid, for example energy storage (electrical, chemical, biological, and heat), and the future of smart grid

Use of MATLAB/Simulink to model, simulate and analyse the dynamic behaviour of a standard smart grid

Discuss in groups popular and latest models of integrating a diverse range of renewable resources to the grid.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the energy demand to determine the technology and methods of energy production		
P1 Evaluate the energy demand of a specific scenario or case study by identifying the required technology and methods of energy production with reasoning or consideration of alternatives.	**M1** Determine the effectiveness and drawbacks of renewable energy systems for short- and long-term impact on energy demands.	**D1** Justify the most suitable technologies and methods of energy production for the local area, backed by relevant data or research.
LO2 Explore current energy efficiency measures, technologies, and policies specific to the building and transportation sectors		
P2 Explore energy efficiency measures, technologies, and policies in the building and transportation sectors suggesting alternatives.	**M2** Provide detailed SWOT analysis of various energy efficiency measures, technologies, and policies in the building and transportation sectors.	**D2** Conduct an impact analysis of current and emerging energy efficiency measures, technologies and policies in the building and transportation sectors, with insightful recommendations or predictions for future developments.

Pass	Merit	Distinction
LO3 Analyse the control techniques of power electronics for renewable energy systems		
P3 Analyse the control techniques of power electronics for a given renewable energy system, applying understanding of the key concepts and practices.	**M3** Provides an analysis of the control techniques of power electronics for renewable energy systems, demonstrating a clear understanding of the theoretical principles and practical applications, including identification of strengths and weaknesses of various techniques.	**D3** Conduct an in-depth impact analysis of the control techniques of power electronics for renewable energy systems, demonstrating a superior understanding of principles, applications and future trends.
LO4 Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid		
P4 Investigate key impacts of renewable resources on the grid and issues associated with integrating such resources	**M4** Evaluate the impacts of renewable resources on the grid and the issues with integration, demonstrating an understanding of the complexities involved.	**D4** Synthesise the challenges and potential solutions, drawing on relevant case studies and cutting-edge research.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ackermann T. (2012) *Wind Power in Power Systems*. Wiley.

Bhimbhra P.S. (2012) *Power Electronics*. Khanna Publishers.

Cole B. (Editor) (2023) *Power Electronics: Devices, Circuits and Applications* (Hardback). Clanrye International.

Duffie J.A. and Beckman W. A. (2013) *Solar Engineering of Thermal Processes*. Wiley.

Dugan R.C., McGranaghan M.F., Santoso S., and Beaty H.W. (2012) *Electrical Power Systems Quality*, Third Edition (Electronics) Hardcover – Illustrated. McGraw Hill.

Fekik A., Ghanes M. and Denoun H. (Editors) (2023) *Power Electronics Converters and their Control for Renewable Energy Applications* (Paperback). Elsevier Science & Technology.

Kassakian J.G., Perreault D.J., Verghese G.C. and Schlecht M.F. (2023) *Principles of Power Electronics* (Hardback). Cambridge University Press.

Kumar S., Singh B., and Singh A.K. (Editors) (2023) *Recent Advances in Power Electronics and Drives: Select Proceedings of EPREC 2021 − Lecture Notes in Electrical Engineering 852* (Paperback). Springer.

Kumar N., Guerrero J.M., Kastha D., and Saha T.K. (Editors) (2022) *Power Electronics for Next-Generation Drives and Energy Systems. Volume 1: Converters and control for drives*. IET Digital Library.

Masters G.M. (2013) *Renewable and Efficient Electric Power Systems* (IEEE Press) Hardcover – Illustrated. Wiley-IEEE Press.

Na (2014) *A Course in Electrical and Electronic Measurements and Instrumentation* (Nineteenth Revised Edition 2011 Reprint 2014) Paperback. NA.

Peake S. (Editor) (2017) *Renewable Energy: Power for a Sustainable Future* Paperback – Illustrated. OUP Oxford.

Rashid M.H.(Editor) (2023) *Power Electronics Handbook* (Hardback). Elsevier.

Vittal V., Mccalley J.D., Anderson P.M., and Fouad A.A. (2019) *Power System Control and Stability (IEEE Press Series on Power and Energy Systems)* Hardcover. Wiley-IEEE Press.

Willis H.L. (Editor) (2018) *Distributed Power Generation: Planning and Evaluation*. eBook. Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Energies

Energy and Buildings

Energy Policy

IEEE Power and Energy Magazine

IEEE Transactions on Power Electronics

International Journal of Electrical Power and Energy Systems

International Journal of Sustainable Transportation

Journal of Cleaner Production

Renewable and Sustainable Energy Reviews

Renewable Energy

Transportation Research Part D: Transport and Environment

Links

This unit links to the following related units:

Unit 5018: Sustainability

Unit 5020: Utilisation of Electrical Power.

Unit 5012: Industrial Systems

Unit Code: **K/651/0866**

Level: **5**

Credits: **15**

Introduction

The speed and efficiency of many industrial processes is due, largely, to the control systems selected for the application and the engineer’s ability to apply the most appropriate technology for their operation.

This unit presents a structured approach to the development of advanced electronic solutions in a range of modern industrial situations. An essential requirement here is the engineer’s ability to utilise the most appropriate technology for each application, to ensure the most efficient monitoring and control of variables such as pressure, temperature, and speed.

Among the topics included in this unit are techniques and applications of electrical and electronic engineering, as they apply to various branches of industry, such as component handling, controlling actuators, responding to change of circumstances in a process, or security issues of connected sensors and systems.

On successful completion of this unit students will be able to learn about system elements and their overall characteristics, and analytically assess the accuracy and repeatability of a range of instruments.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Appraise the main elements of an electronically controlled industrial system

LO2 Review and specify the interface requirements between electronic, electrical, and mechanical transducers and controllers

LO3 Employ practical and computer-based methods to design and test a measurement system

LO4 Apply appropriate analytical techniques to predict the performance of a given system.

Essential Content

LO1 **Appraise the main elements of an electronically controlled industrial system**

Fundamental concepts of industrial systems:

Discrete control

Input and output devices; open and closed loop systems

System elements, principles, and applications of important and representative AC, DC and Stepper motors, and various types of linear actuators.

LO2 Review and specify the interface requirements between electronic, electrical, and mechanical transducers and controllers

Interfacing and transducers:

Discrete automation using relays and solenoids, AC and DC motors, pneumatic, hydraulic and electrical actuators, and other transducers and devices for measuring and comparing physical parameters

Sensors, passive and active including, hall effect, thermocouples, proximity, acoustics, RFID

Interfacing between electrical, electronic and mechanical transducers

Practical measurement using sensors and transducers, process actuators for temperature and pressure control including Internet enabled technologies.

LO3 **Employ practical and computer-based methods to design and test a measurement system**

System modelling and analysis:

The use of transfer functions to help predict the behaviour and constancy of an industrial process, including accuracy, resolution and tolerances, repeatability and stability, sensitivity and response time

Dealing with error and uncertainty in industrial systems

Use of computer packages in measurement and control, and dealing with uncertainty and errors in systems (including Industry 4.0 systems).

LO4 Apply appropriate analytical techniques to predict the performance of a given system

Use of analytical techniques for performance measurement. Examples of analytical techniques could include: the Monte Carlo method to predict locations and timings of machine failure for maintenance planning, or regression modelling to analyse raw material influence on production outputs

Industry 4.0 and current trends in technology, including the future of industrial systems, seamless integration of systems, the impact of digital developments, the increase of wireless and remote control, Internet of Things, and big data.

Management and strategic issues relating to Industry 4.0, specifically, security and hacking issues of connected sensors and systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Appraise the main elements of an electronically controlled industrial system		
P1 Appraise the key components used in an electronically controlled industrial system. **P2** Review the main concepts underlying electronically controlled industrial systems.	**M1** Analyse the characteristics of an electronically controlled industrial system by applying a variety of techniques to the solution of a given problem.	**D1** Critically examine the performance of an electronically controlled system to make recommendations for improvement.
LO2 Review and specify the interface requirements between electronic, electrical, and mechanical transducers and controllers		
P3 Review the interface requirements between electronic, electrical, and mechanical transducers and controllers. **P4** Justify the choice of transducers and controllers for a given task.	**M2** Predict the behaviour of an electronically controlled industrial system by applying a variety of transducers to the solution of a given problem and choose a 'best' solution.	**D2** Critically investigate the behaviour of a given control system to compare different electrical, electronic and mechanical approaches to control.
LO3 Employ practical and computer-based methods to design and test a measurement system		
P5 Employ any two practical and computer-based methods to design and test a measurement system. **P6** Explain the use of practical and analytical methods in creating and testing a measurement system.	**M3** Interpret the characteristics and behaviour of an existing electronic measurement system by applying a variety of methods to find a solution to a given problem.	**D3** Develop an evaluative report on the performance of an ideal measurement system required to function within Industry 4.0 operations.
LO4 Apply appropriate analytical techniques to predict the performance of a given system		
P7 Apply the main analytical techniques to explain the performance of a given system.	**M4** Evaluate the characteristics of an electronically controlled industrial system by applying a variety of analytical techniques to the solution of a given problem.	**D4** Analyse an existing industrial system by using appropriate analytical techniques to provide justified recommendations to improve performance.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Badiru A.B. and Omitaomu O.A. (2023) *Systems 4.0: Systems Foundations for Industry 4.0.* 1st Ed. CRC Press.

Balamurugan S. (Editors) (2022) *Industrial Internet of Things: Technologies and Research Directions.* 1st Ed. CRC Press.

Bidanda B. (2022) *Maynard's Industrial and Systems Engineering Handbook.* 6th Ed. McGraw-Hill.

Bird J. (2022) *Electrical Circuit Theory and Technology*. 7th Ed. Routledge.

Bishop O. (2021) *Electronics: A First Course.* 3rd Ed. Routledge.

Hughes E. et al. (2016) *Electrical and Electronic Technology*. Pearson.

Massaro A. (2021) *Electronics in Advanced Research Industries: Industry 4.0 to Industry 5.0 Advances.* Wiley-IEEE Press.

McMillan G.K. and Vegas P.H. (2019) *Process/Industrial Instruments and Controls Handbook.* 6th Ed. McGraw-Hill.

Patin N. (2016) *Power Electronics Applied to Industrial Systems and Transports.* 1st Ed. Elsevier.

Peacock B. and Badiru A.B. (2023) *Industrial Engineering in Systems Design: Guidelines, Practical Examples, Tools, and Techniques.* 1st Ed. CRC Press.

Rehg J.A. and Sartori, G.J. (2005) *Industrial Electronics*. Prentice-Hall.

Sharma A., Jangir S.K., Kumar M., Choubey D.K., Shrivastava T. and Tan R.R., Aviso K.B. and Promentilla M.A.B. (2018) *Input-Output Models for Sustainable Industrial Systems: Implementation Using Lingo (Lecture Notes in Management and Industrial Engineering).* Springer.

Wilamowski B.M. and Irwin J.D. (2011) *The Industrial Electronic Handbook: Fundamentals of Industrial Electronics*. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Future Industrial Systems: Opportunities and Challenges

IEEE Transactions on Industrial Informatics

Intelligent Industrial Systems

International Journal of Industrial and Systems Engineering

Journal of Industrial and Systems Engineering

Journal of Industrial Information Integration

Journal of Industrial System Engineering and Management

Journal of Manufacturing Systems

Journal of Mechanical Design Transactions of the ASME

Technovation

Links

This unit links to the following related units:

Unit 4016: Instrumentation and Control Systems

Unit 4019: Electrical and Electronic Principles.

Unit 5013: Embedded Systems

Unit Code: L/651/0867

Level: 5

Credits: 15

Introduction

Embedded systems are a key element of modern engineering systems, applied in areas as diverse as agriculture, automotive, medical, and space, in industrial setting, and in the home and office. In many cases, embedded systems are linked together in networks and consist of a combination of hardware and software components to performs specific functions. Embedded systems are the basis of modern engineering design and practice, notably in machine-to-machine communication and the Internet of Things (IoT).

This unit develops the knowledge of computer hardware, focussing on the small, low-cost type of computer (i.e., a *microcontroller*), that are used in embedded systems. It then develops skill in selecting peripheral devices that operate external to the microcontroller and interface with it; generally, these relate to sensors, actuators, human interface, or data transfer. In parallel with this, students will be developing programming skills, writing programmes which download straight to the microcontroller, to interact with its external circuit. Students will also explore the wider context of embedded systems, learning how they are applied in 'hi-tech' applications, in many cases revolutionising our ability to undertake certain activities.

Unit assessment will require the design, development, and testing of an embedded system, to meet a given design brief; this will develop skills which are in much demand in industry. A written assignment, exploring one or more of the many fast-moving embedded system applications in use today, will also be completed.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine embedded system technology

LO2 Design an embedded system using available interfaces to perform a range of functions

LO3 Implement embedded system design by writing code in an appropriate programming language, to simulate, test and debug the system

LO4 Evaluate applications of embedded systems in the wider environment.

Essential Content

LO1 Examine embedded system technology

Embedded systems:

Embedded system overview

Embedded systems by example: Microcontroller/microprocessor based systems; architecture, key units and peripherals, interfaces, memory etc.; industry case studies

Embedded system design process

Hardware (CPU, memory, digital and analogue I/Os etc.)

Software (IDE, Python, simplified C/C++ etc.)

Communication protocols (network, wireless, IoT)

LO2 Design an embedded system using available interfaces to perform a range of functions

Simple digital interfacing:

Arduino shields and carriers to utilise a range of components

Switches, light emitting diodes (LEDs), keypads, and 7-segment displays

DC load switching (e.g., of small motor or solenoid), use of PWM to provide variable DC motor speed control

Interfacing to external devices

ADC application, including range and resolution.

LO3 **Implement embedded system design by writing code in an appropriate programming language, to simulate, test and debug the system**

The development cycle:

Integrated Development Environment (IDE), Assembler and High-Level Languages, compilers, simulators, completing an in-circuit debug

Devising a code structure e.g., using flow diagrams and pseudo code.

Programming languages and codes:

Review of an appropriate high level programming languages Language constructs − data types, programme flow, looping, branching, and conditional statements etc.

Developing application code: initialisation, data input, conditional branching and looping, data output

Latest IDEs for controller programming

Development using e.g.: Python, C/C++ or a suitable language/platform

Code simulation, download, test plans and testing (e.g. unit testing, system testing, acceptance testing), and debug, troubleshoot.

LO4 **Evaluate applications of embedded systems in the wider environment**

Review of application of embedded systems:

Using example sectors e.g., motor vehicle, smart buildings, medical, office, wearable. Review possible limiting factors in an embedded design e.g., power supply, reliability, security

Review of current trends in embedded systems, including the Internet of Things (IOT), machine learning, cloud computing, artificial intelligence, sustainability, green engineering and so on

Embedded systems for future societies

Review and select technologies for performance optimisation

Embedded systems and Industry 4.0/5.0. Integration and impact on organisations

Suitability of embedded systems to meet accessibility, inclusive and diversity considerations; application context, job roles, and engagement with stakeholder groups.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine embedded system technology		
P1 Examine the main architecture of a selected microcontroller. **P2** Explain the function of the main microcontroller elements.	**M1** Analyse methods by which controllers communicate with external environment	**D1** Critically analyse the microcontroller architecture selected in terms of its limitations and suitability for various applications.
LO2 Design an embedded system using available interfaces to perform a range of functions		
P3 For a given application, design an embedded system to meet the specified functional requirements.	**M2** Review selected devices in terms of their functionality for a given design task. **M3** Discuss the trade-off for the choices made in terms of performance, power, cost etc. to meet the given design objectives.	**D2** Critically appraise the functionality of the entire embedded system, including further design improvements.
LO3 Implement embedded system design by writing code in an appropriate programming language, to simulate, test and debug the system		
P4 Implement an embedded system by writing a well-structured code to perform a selection of functions as per the design. **P5** Develop an initial test plan to demonstrate a subset of functionality of the proposed system.	**M4** Produce a refined test plan to test all functions of the given system.	**D3** Evaluate a fully working embedded system with real peripherals, in discussion with a peer group of developers.
LO4 Evaluate applications of embedded systems in the wider environment		
P6 Evaluate current uses of embedded systems in a chosen sector.	**M5** Explore emerging trends in developing embedded systems, for example artificial intelligence, the Internet of Things or sustainability.	**D4** Critically appraise ongoing research on future applications of embedded systems, clearly identifying societal demands and needs and recognising technical and economic factors in a global context.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bertolotti C. and Hu T. (2020). *Embedded Software Development: The Open-Source Approach*. 1st Ed. CRC Press

Blum J. (2019) *Exploring Arduino: Tools and Techniques for Engineering Wizardry*. 2nd Ed. Wiley

Cheich M. (2021) *Arduino book for beginners*. eBook. Kindle edition.

Hobbs C. (2020) *Embedded Software Development for Safety-Critical Systems.* Auerbach Publications

Ibrahim D. (2019) *ARM-based Microcontroller Projects Using mbed*. 1st Ed. Newnes

Lacamera D. (2023) *Embedded Systems Architecture*. 2nd Ed. Packt Publishing

Monk S. (2023) *Programming Arduino: Getting Started with Sketches* 3rd Ed. McGraw Hill TAB

Motahhir S. (2023) *Smart Embedded Systems and Applications*. 1st Ed. River Publishers

Pachari R.K., Pandey J.K., Sharmu A., Nautiyal O. and Ram M. (2021) *Applied Soft Computing and Embedded System Applications in Solar Energy*. CRC Press

Rossi M., Toscani N. Mauri M. and Dezza F.C. (2022) *Introduction to Microcontroller Programming for Power Electronics Control Applications – Coding with MATLAB and Simulink*. 1st Ed. CRC Press

White E. (2023) *Making Embedded Systems*. 2nd Ed. O'Reilly Media, Inc.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Design Automation for Embedded Systems

IEEE Embedded Systems Letters

IEEE Internet of Things Magazine

IEEE Internet of Things Journal

International Journal of Embedded Systems

Journal of Embedded Systems

Journal of System Architecture

Microprocessors and Microsystems

Links

This unit links to the following related units:

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit 5021: Further Control Systems Engineering.

Unit 5014: Analogue Electronic Systems

Unit Code: M/651/0868

Level: 5

Credits: 15

Introduction

Analogue electronic systems are still widely used for a variety of very important applications and this unit explores some of the specialist applications of this technology.

The aim of this unit is to further develop students' understanding of the application of analogue devices in the design of electronic circuits. Students will investigate the design and testing of electronic systems based on a sound theoretical knowledge of the characteristics of electronic devices supported by Electronic Computer Aided Design (ECAD) tools, and then construct and test sample physical circuits. Students will be able to explain the characteristics of analogue and digital subsystems and the representation and processing of information within them.

Upon completion of this unit students will be aware of techniques employed in the design and evaluation of analogue subsystems used in the development of complete electronic systems.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Analyse single stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances

LO2 Develop functional subsystems through an understanding of the characteristics of operational amplifiers

LO3 Assess techniques for the conversion of signals between analogue and digital formats

LO4 Design electronic circuits using physical components.

Essential Content

LO1 **Analyse single stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances**

Bipolar Junction Transistor models:

The theory of operation of the Bipolar Junction Transistor (BJT), together with DC biasing conditions of BJT for linear amplifier applications

Characteristics of common emitter, common collector and common base amplifier configurations

DC h_{FE} and small signal common emitter h-parameter model and the common emitter hydrid-π model of the BJT

Show g_m =~ I_C/26mV for silicon BJT at room temperature.

Bipolar Junction Transistor small signal amplifiers:

Four-resistor BJT common-emitter amplifier analysis and its predicted DC and AC voltage gain

ECAD tools to be used to determine the mid-band voltage gain and input and output resistances.

The effect of input, output and emitter decoupling capacitors and tuned L-C collector load.

Bipolar Junction Transistor large signal amplifiers:

Class A, B, AB, C and D amplifiers and applications

Use of ECAD to investigate the characteristics of a sample power amplifier circuit to include frequency response.

Field Effect Transistor models:

The theory of operation of the Field Effect Transistor (FET) and the Metal Oxide Semiconductor FET (MOSFET)

Application of FETs and MOSFETs in switching circuits and linear amplifiers, including complementary MOSFET stages

Apply FET AC equivalent circuit models

Examples of specific applications of FET that have been developed for specialist applications

Use of ECAD tools, to simulate and analyse the behaviour of switching and linear amplifier circuits.

LO2 **Develop functional subsystems through an understanding of the characteristics of operational amplifiers**

Operational amplifier:

Components and characteristics

Circuit configuration and operation

Ideal operational amplifier model, specifications of practical operational amplifiers

Characteristics of the operational amplifier with negative feedback applied.

Operational amplifier applications:

Description of a range of subsystems, including the voltage comparator, linear voltage regulator, switched mode voltage regulator, differentiator, integrator, active filters, Schmitt trigger and Schmitt oscillator

Sub-system specifications and evaluations in time and frequency domains, as appropriate

Use of ECAD tools to simulate and analyse the behaviour above listed circuits.

LO3 **Assess techniques for the conversion of signals between analogue and digital formats**

The characteristics of information represented electronically:

Comparison of the implications of capturing, processing and storing information represented by analogue signals and by digital data, including amplitude range, frequency range, accuracy, resolution, linearity, drift, noise and signal-to-noise ratio.

Digital to analogue convertors (DAC) and analogue to digital converters ADC):

Evaluation and comparison of digital to analogue converters using calculations and simulation based on the binary weighted resistor, the R/2R ladder network techniques, successive approximation, segmented configuration, to also include an introduction to delta-sigma convertor

Evaluate and compare of analogue to digital converters based on the single ramp, successive approximation and parallel comparator (flash) techniques, sigma-delta and delta-sigma

Examples of commercially available converters and the implementation of analogue input and output ports to digital processing devices found within embedded systems.

LO4 **Design electronic circuits using physical components**

Sub-system design, implementation, and evaluation:

Examples of electronic subsystems

Development of specifications to achieve a predefined function Design the circuits to achieve this function including components selection (resistors, capacitors, inductors, transistors, diodes, op-amps, sensors, and connectors) as well as input and output signals to be used for circuit testing in simulation and bench testing

Simulation of design using ECAD tools

Implementation, integration, and evaluation aspects

Building of circuits as designed, application of a range of appropriate bench tests to evaluate its operation, and comparing its actual operation to the design specifications and the simulation results.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse single stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances		
P1 Analyse key aspects of single stage amplifier circuits through calculations and simulation to produce input and output waveforms.	**M1** Discuss assumptions and discrepancies between simulation results and circuit calculations.	**D1** Propose and implement justified and operable recommendations for changes to the specifications of the circuits and repeat the simulation to produce improved results.
LO2 Develop functional subsystems through an understanding of the characteristics of operational amplifiers		
P2 Develop the key components of an operational amplifier configuration with negative feedback. **P3** Determine the operation of subsystems from the ideal model of the operational amplifier and by simulation for a range of input signals.	**M2** Design operational amplifier subsystems simulated in time and frequency domains. **M3** Critically analyse simulation results with reference to the expected results.	**D2** Communicate to specialist audiences the use of manufacturers' data sheets, including critical parameters for component selection in practical circuits design.

Pass	Merit	Distinction
LO3 Assess techniques for the conversion of signals between analogue and digital formats		**D3** Create a given range of DAC circuit simulations to critically evaluate the implications of resolution and conversion time on accuracy and noise.
P4 Assess the limitations of representing information in both analogue and digital form. **P5** Specify the technical characteristics of converters in terms of meeting a given set of requirements.	**M4** Evaluate the characteristics and the limitations of specific converter topologies and their example applications.	
LO4 Design electronic circuits using physical components		**D4** Present circuit designs to specialist audiences, showing the variation of circuit function in simulations as a result of design changes or component tolerances.
P6 Design an electronic circuit supported by a written description. **P7** Simulate a working electronic circuit using a set of chosen components. **P8** Construct and test the design on the bench with a justification of the testing method.	**M5** Critically analyse design equations, simulation, and bench test results ensuring discrepancies are recorded and explained using graphical representation.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird Jo. (2022) *Bird's Electrical Circuit Theory and Technology*. 7th Ed. Routledge

Bishop 0 (2021) *Electronics: A First Course*. 3rd Ed. Routledge.

Bugg D.V. (2021) *Electronics: Circuits, Amplifiers and Gates*. 2nd Ed. CRC Press.

Makarov S., Ludwig, R. and Bitar, SJ. (2019) *Practical Electric Engineering.* 2nd Ed. Springer

Lathi B.P. and Zhi D. (2009) *Modern Digital and Analog Communications Systems. Oxford Series in Electrical and Computer Engineering.* 4th Ed. Oxford University Press.

Storey N. (2013) *Electronics: A Systems Approach*. 5th Ed. Pearson.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Analogue Design Journal

Analog Integrated Circuits and Signal Processing

IEEE Transactions on Circuits and Systems II

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 5015: Manufacturing Systems Engineering

Unit Code: J/615/1516

Level: 5

Credits: 15

Introduction

Manufacturing systems engineering is concerned with the design and on-going operation and enhancement of the integrated elements within a manufacturing system, which is a very complex activity, even for simple products. The art of manufacturing systems engineering is essentially designing systems that can cope with that complexity effectively.

The aim of this unit is to develop students' understanding of that complexity within a modern manufacturing environment. Among the topics covered in this unit are: elements that make up a manufacturing system, including production engineering, plant and maintenance engineering, product design, logistics, production planning and control, forecast quality assurance, accounting and purchasing, all of which work together within the manufacturing system to create products that meet customers' requirements.

On successful completion of this unit students will be able to explain the principles of a manufacturing system and consider how to design improvements. They will be introduced to all the elements that make up a modern manufacturing system, and they will learn how to optimise the operation of existing systems through discerning use of monitoring data. Some of the elements will be developed in greater depth; of particular importance will be looking at the systems of production planning and control, which are the day-to-day tools used to manage the manufacturing system effectively.

Learning Outcomes

By the end of this unit a student will be able to:i

LO1 Illustrate the principles of manufacturing systems engineering and explain their relevance to the design and enhancement of manufacturing systems

LO2 Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system, and then develop an appropriate future state for that system

LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system

LO4 Define the responsibilities of manufacturing systems engineering and review how they enable successful organisations to remain competitive.

Essential Content

LO1 **Illustrate the principles of manufacturing systems engineering and their relevance to the design and enhancement of manufacturing systems**

Manufacturing systems elements:

Elements to be considered include quality, cost, delivery performance and optimising output

Problem-solving and managing complexity, maintenance scheduling and planning, resource planning and productivity

Effect of testing and data analysis on performance.

LO2 **Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system, and then develop an appropriate future state for that system**

Analysis tools:

Introduction to value stream mapping, and the value of both current state mapping and future state mapping

Bottle-neck analysis, by using process improvement tools and techniques e.g. value stream analysis, simulation, kanban

Using key performance indicators to understand the performance of a manufacturing system e.g. overall equipment effectiveness, lead-time, cycle time, waiting time, yield, delivery performance, safety metrics

Reviewing key performance indicators; methods for presenting metrics and performance e.g. balanced scorecards, performance dashboards, Andon boards, Gemba walks.

LO3 **Outline the impact of different production planning approaches on the effectiveness of a manufacturing system**

Production planning approaches:

Examples of production planning strategy: push vs pull factors, kanban systems, make to stock, make to order and engineer to order

Production planning approaches such as batch and queue, pull/kanban, just-in-time, modular design, configuration at the final point, and master scheduling.

Production planning management tools:

Enterprise Resource Mapping (ERP) systems, Material Resource Planning (MRP 2) and Manufacturing Execution systems, ability to managing complexity and resourcing through information technology

Industrial engineering issues: the importance of standard times and the impact on productivity and the costing of products. Standard work underpins the repeatability of process and quality control.

LO4 **Review the functions of manufacturing systems engineering and how they enable successful organisations to remain competitive.**

Effectiveness of manufacturing systems:

Plant layout design, planning and control, productivity and continuous improvement, quality control and equipment effectiveness

Return on investment and capital expenditure, control of the cost of planned maintenance

Manufacturing information technology: the supply of data from the process to decision-makers e.g. failure modes for both product and system, maintenance and down time data, standard times for production, material control, energy usage.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Illustrate the principles of manufacturing systems engineering and their relevance to the design and enhancement of manufacturing systems		
P1 Illustrate the principles of manufacturing engineering. **P2** Explain the relevance of manufacturing systems engineering to the design of a manufacturing system.	**M1** Evaluate the impact that manufacturing systems have on the success of a manufacturing organisation.	**D1** Apply value stream mapping to a production process to evaluate the efficiency of that process by using the current state map to suggest improvements.
LO2 Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system, and then develop an appropriate future state for that system		
P3 Apply value stream mapping to visualise a production process.	**M2** Identify optimisation opportunities through value stream mapping of a production process.	**D2** Review value stream mapping against other production planning methodologies and justify its use as a production planning tool.

Pass	Merit	Distinction
LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system		
P4 Identify the common production planning approaches and state their impact on manufacturing systems. **P5** Define the types of manufacturing approach, such as make to stock, make to order and engineer to order.	**M3** Evaluate the effectiveness of production planning methods. **M4** Explore the effectiveness of common production planning techniques to identify which production approach they complement.	**D3** Justify the most appropriate production planning technique and its suitability for a particular manufacturing approach, such as make to stock, make to order, or engineer to order.
LO4 Review the functions of manufacturing systems engineering and how they enable successful organisations to remain competitive.		
P6 Define the core responsibilities of a manufacturing systems engineer. **P7** Identify the key contributing success factors of a manufacturing system.	**M5** Evaluate the impact that a manufacturing systems engineering has on successful manufacturing organisations.	**D4** Critically consider the elements of an existing manufacturing system to appraise why this is successful.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bicheno, J. and Holweg, M. (2009) *The Lean Toolbox*. 4th Ed. PICSIE Books.

Chopra, S. and Meindl, P. (2015) *Supply Chain Management: Strategy, Planning, and Operation (Global Edition).* 6th Ed. Pearson.

Groover P. M. (2019) *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*. 7th Ed. Wiley.

Huang Y., Wang L., and Liang S. Y. (2019) *Handbook of Manufacturing.* World Scientific Publishing Company.

Kalpakjian S. and Schmid S. (2022) *Manufacturing Engineering and Technology*. 8th Ed. Pearson.

Slack, N. (2013) *Operations Management*. 7th Ed. Pearson.

Womack, J., Jones, D. and Roos, D. (1990) *The Machine That Changed the World*. Free Press.

Websites

http://www.industryweek.com/	Industry Week Five Benefits of an MES (Article)

Links

This unit links to the following related units:

Unit 5016: Lean Manufacturing

Unit 5017: Advanced Manufacturing Technology

Unit 5018: Sustainability.

Unit 5016: Lean Manufacturing

Unit Code: M/651/0877

Level: 5

Credits: 15

Introduction

Lean manufacturing is a systematic approach to minimising waste in a manufacturing system, by focusing on the activities that add the most value through the eyes of the customer. The basis of lean manufacturing originated in the car industry and was developed by Toyota in Japan. Lean is now used extensively worldwide, in all types and size of organisation, to improve international competitiveness. It is therefore crucial for manufacturing engineers to be able to design and operate manufacturing systems that employ lean successfully.

The aim of this unit is to introduce students to the principles and processes of lean manufacturing, so that they can become an effective and committed practitioner of lean in whatever industry sector they are employed in. To do this, the unit will explore the tools and techniques that are applied by organisations practicing lean. The students will consider both the benefits and challenges of using lean manufacturing, and become sufficiently knowledgeable about the most important process tools and techniques to be able to operate and use them.

Among the topics included in this unit are: scoping and defining lean manufacturing, the benefits and challenges of adopting Lean thinking, , common tools and techniques associated with lean manufacturing and process improvement, and the most appropriate improvement tool(s) to tackle a problem.

On successful completion of this unit students will be able to learn about the common principles of lean manufacturing. a range of the process improvement tools used within lean manufacturing, and effective communication skills in order to lead the process of continuous improvement across an organisation.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success

LO2 Evaluate the lean approach applied to the modern manufacturing environment

LO3 Specify a range of the process improvement tools used within lean manufacturing

LO4 Demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation.

Essential Content

LO1 **Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success**

Scoping and defining lean manufacturing:

The common principles of lean manufacturing philosophy

Origins of lean, Toyota production system.

Defining lean and its importance to the customer

Identifying and eliminating material and process waste that adds no value from the customer's perspective

Standardization, line balancing and Takt time.

Benefits and challenges of adopting lean:

Why an organisation would consider adopting a lean philosophy

Productivity, quality, customer satisfaction, delivery performance

The benefits of a lean organisation to the customer, the employees, and the shareholders

Outline the benefits of lean in terms of cost, quality, delivery, customer satisfaction, management complexity and cost to serve

Challenges of implementation: change management, managing expectation, empowerment, motivation, 'burning platform', investment, supply chain.

LO2 **Evaluate the lean approach applied to the modern manufacturing environment.**

Lean Production Systems:

Toyota lean production system and other modern lean production systems for manufacturing

Research lean manufacturing and identify its fundamental elements and the motivation behind creation

Compare Lean thinking with the recognised theory and production systems publicised by other global manufacturers: how do they differ and how they are similar?

How the common principles are now being adopted outside manufacturing

Consider the core principles of lean thinking to support Industry 4.0.

LO3 **Specify a range of the process improvement tools used within lean manufacturing**

Common tools and techniques associated with lean manufacturing and process improvement:

Six Sigma, 8 Wastes, Workplace organisation such as 5S's (sort, set in order, shine, standardise and sustain), Kaizen, continuous flow, kanban (pull System), just-in-time (JIT), lean simulation activities, value stream mapping, Poke Yoke (error proofing), 5 Whys (Root Cause Analysis), Total Preventive Maintenance (TPM), Total Quality Management (TQM)

Plan-do-check-act (PDCA), Single Minute Exchange of Die (SMED), A3 Reporting, Visual Management.

Selecting the most appropriate improvement tool to tackle a problem:

Tools for improving quality and delivery. Types of faults/defects recorded and analysed to improve future performance, Failure Mode and Effects Analysis (FMEA), Fishbone, Practical Problem Solving (PPS), Process Failure Mode and Effects Analysis (PFMEA)

Equipment needed to perform data collection and analysis, e.g., automatic test equipment, visual automatic inspection system, data acquisition equipment, software programmes to analyse the data and inform operators in real time, analysis and interpretation of data for documentation such as Parts Per Million (PPM and quality adherence.

Use of Industry 4.0 tools/technologies and integration (e.g. automation, robots, PLCs, digital systems and manufacturing engineering systems).

LO4 **Demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation**

Communication:

Facilitate a small group in the application and use of one of the lean tools (e.g., 5 Whys technique, A3 Report)

Evaluate factors that influence engagement within a group, facilitation skills development, address continuous improvement and change management processes.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success		
P1 Examine how lean manufacturing principles can improve business performance.	**M1** Analyse the benefits of adopting lean manufacturing. **M2** Analyse the key challenges encountered when implementing lean manufacturing.	**D1** Critically evaluate the advantages and disadvantages of implementing a lean production system.
LO2 Evaluate the lean approach applied to the modern manufacturing environment		
P2 Evaluate the key principle of lean thinking that will support the next industrial revolution. **P3** Research and assess alternatives to lean production system approaches. **P4** Examine the origins of lean and specify its early applications.	**M3** Assess key barriers to the implementation of lean thinking into the modern manufacturing environment.	**D2** Evaluate lean elements that are critical in making the approach successful in supporting Industry 4.0.
LO3 Specify a range of the process improvement tools used within lean manufacturing		
P5 Specify which tools are commonly associated with lean manufacturing and what contexts they would be applied in.	**M4** Evaluate how the most common lean tools can be applied to eliminate waste in a manufacturing process.	**D3** Develop a justified recommendation for a lean tool to be applied in addressing a specified process improvement.
LO4 Demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation		
P6 Demonstrate skills in developing a communication approach to manage change in an organisation.	**M5** Evaluate the impact of this communication approach, including an evaluation of impact on employees and personal effectiveness.	**D4** Critically evaluate the importance of the higher order skills required to successfully deploy change for continuous improvement in an organisation.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ajay, Singh H., Parveen and Almangour B. (Editors) (2023) *Handbook of Smart Manufacturing − Forecasting the Future of Industry 4.0.* 1st Ed. CRC Press.

Blackwell D., George M.L. and Rajan D. (2019) *Lean Six Sigma in the Age of Artificial Intelligence: Harnessing the Power of the Fourth Industrial Revolution.* 1st Ed. McGraw-Hill.

Cudney E.A., Furterer S. and Dietrich D. (Editors) (2021) *Lean Systems − Applications and Case Studies in Manufacturing, Service, and Healthcare.* CRC Press.

Díaz-Reza J.R., García-Alcaraz J.L. and García A.S.M. (2022) *Best Practices in Lean Manufacturing: A Relational Analysis.* Springer.

Dillon A.P. (2019) *A study of the Toyota production system: From an Industrial Engineering Viewpoint.* Routledge.

Pink S. (2022) *Emerging Technologies/Life at the Edge of the Future.* 1st Ed. Routledge.

Silva F. and Ferreira P.L. (2019) *Lean Manufacturing: Implementation, Opportunities and Challenges*. Nova Science Publishers.

Tarantino A. (2022) *Smart Manufacturing: The Lean Six Sigma Way.* Wiley.

Vinodh S. (2023*) Lean Manufacturing: Fundamentals, Tools, Approaches, and Industry 4.0 Integration.* 1st Ed. CRC Press.

Womack, J., Jones, D. and Roos, D. (1990) *The Machine That Changed the World*. Free Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

International Journal of Engineering Business Management

International Journal of Lean Six Sigma

International Journal of Technology (Lean Manufacturing Articles)

Journal of Intelligent Manufacturing

Journal of Manufacturing Processes

Quality Magazine: Lean Manufacturing

Links

This unit links to the following related units:

Unit 5015: Manufacturing Systems Engineering

Unit 5017: Advanced Manufacturing Technology

Unit 5018: Sustainability.

Unit 5017: Advanced Manufacturing

Unit Code: D/651/0880

Level: 5

Credits: 15

Introduction

The ability of successful companies to meet the growing demand of customers is heavily influenced by the development of advanced manufacturing technologies. Customers expect high complexity products, on demand, and with a growing element of customisation. In adopting advanced manufacturing technologies, successful companies will ensure faster time to market of new products, improve products and processes, use new, sustainable, materials, and customise to customer requirements. Manufacturing systems engineering underpins this development.

In order to meet changing customer expectations and gain competitive advantage, focus needs to be applied to developing smart factories and advanced manufacturing technologies. Manufacturing organisations will seek integration between manufacturing technology, high performance computing, the internet, and the product at all stages of its life cycle.

The unit will introduce Industry 4.0, the term that has been adopted to describe the ‘fourth’ industrial revolution currently underway, at present, in the manufacturing and commercial sectors of our society. It is a revolution based on the integration of cyber-physical systems with the Internet of Things and services. For the manufacturing sector, this integration has been enabled by successfully combining high performance computing, the internet and the development of advanced manufacturing technologies. Industry 4.0 is changing the way the world’s most successful companies produce the products that their global customers demand.

On successful completion of this unit students will be able to analyse the use of a range of advanced manufacturing technologies to improve the competitive advantage of the organisations adopting them; digitalisation trends in advanced manufacturing technologies; and develop their own research activities into the latest developments.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine a range of advanced manufacturing processes and their effective application

LO2 Contrast advanced manufacturing technologies to determine their appropriateness for an application or process.

LO3 Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies.

LO4 Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer.

Essential Content

LO1 **Examine a range of advanced manufacturing processes and their effective application**

Manufacturing processes:

Subtractive machining, Pressing and forming, casting, and moulding, joining and soldering, mixing, final assembly, packaging, material handling, quality control/inspection.

Advanced manufacturing processes:

Additive manufacture process, fused deposition modelling, selective laser sintering, selective laser melting, Stereolithography, Powder bed and inkjet head 3D printing.

Thermal processes: Laser Beam Machining, Plasma Arc Machining, Electron Beam Machining

Mechanical processes: Abrasive Jet Machining Abrasive Water Jet Machining Abrasive Flow Machining, hybrid CNC machining (e.g. Millturn)

Hybrid manufacturing processes: additive manufacture and mechanical machining, welding and mechanical milling, laser cutting and electro-discharge machining.

Micro and Nano machining processes.

Types of application or industry:

Industry examples: aerospace, automotive, healthcare, electronics, food and beverage, chemical and pharmaceutical, minerals, oil and gas, retail, fashion

Application examples: assembly, joining, moulding, soldering.

LO2 **Contrast advanced manufacturing technologies to determine their appropriateness for an application or process**

Manufacturing technologies:

High precision robotics and automation: healthcare (components and processes), aerospace, automotive, process control and visualisation through automation technology

Improvement in productivity through greater automation

Quality of manufacturing processes improved through integration of robotics

The application of hybrid processes in the manufacturing and repair of complex components (e.g. the use Hybrid Machine Combining Milling and Additive Manufacturing to manufacture rapid tooling such as moulds and dies).

Examples of using 3D printing and other forms of additive manufacturing to produce medical equipment, spares parts for items that may have become obsolete, mass customisation; what the customer wants, when they want it. Hybrid Additive manufacturing technology (e.g., replacing forming, moulding, pressing), impact on rapid prototyping, availability of spares/obsolete parts, medical components available and customised.

LO3 **Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies**

Manufactured product:

Research the traditional methods used to manufacture an existing product, determine the associated processes required to bring it to market and identify the limitations of these methods and processes

Explore how advanced manufacturing technology could be applied to produce this product and suggest how applying such processes would influence its production, environmental impact, costs, time to market and customer satisfaction (e.g., healthcare/medical such as hip joint, traditional method vs mass customisation and the possible use of additive layer manufacture)

Additive layer manufacture and its availability is opening up new markets, but also new business models for organisations; explore the future possibilities for self-serve/or self-production of items.

LO4 Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer

Key technological drivers and Industry 4.0:

Industry 4.0 – latest developments and future trends in advanced manufacturing sector

Internet of Things: over time industry has transformed from being local-based to communication-based technology; the possibilities for connected technology and connected factories are ever increasing

Cyber-physical systems: collaborative robotics and highly integrated manufacturing systems

Mass customisation: growing demand and desire for individual products; advanced manufacturing technology and the ability to manage complexity

Digitalisation and increased automation; the ability to simulate and create a digital twin has the potential to dramatically reduce time to market

The drive to increase efficiency requires innovation and innovative technology; Net zero, renewable energies, and waste reduction

Uses and trends in data collection systems, data formats, data analytics and dashboards

Big data; the development of an ever-connected production environment alongside cloud computing; challenges with a stream of production data and the need to analyse this in order to make timely informed decisions Discussion in groups involving industry case studies and impact of trending innovations.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine a range of advanced manufacturing processes and their effective application		
P1 Examine any two advanced manufacturing processes or technologies with examples of where they are most effective.	**M1** Compare a traditional manufacturer to one employing advanced manufacturing to discuss the fundamental differences.	**D1** Research and evaluate a manufactured product and identify the technology used.
LO2 Contrast advanced manufacturing technologies to determine their appropriateness for an application or process		
P2 Contrast advanced manufacturing technologies to determine their appropriateness for an application or process.	**M2** Explore how advanced manufacturing could be applied, and give examples of where technology would be suited.	**D2** Examine the potential justification for an organisation to invest in advanced manufacturing technology.
LO3 Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies		
P3 Analyse an existing manufactured product and the key technology used to produce the item.	**M3** Evaluate the effectiveness of the current method to suggest an alternative advanced manufacturing technology.	**D3** Critically evaluate the impact on both the customer and the manufacturer of using advanced manufacturing technology rather than the existing method.
LO4 Evaluate the key technological drivers of Industry 4.0 – the next industrial revolution to determine the impact on both manufacturers and the consumer		
P4 Evaluate the concept of a 4th industrial revolution. **P5** Examine the key technological drivers for Industry 4.0.	**M4** Evaluate the impact of advanced manufacturing on both manufacturers and the customer.	**D4** Justify the types of industry or product that would benefit most from an innovative advanced manufacturing approach.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ajay, Singh H., Parveen and Almangour B. (Editors) (2023) *Handbook of Smart Manufacturing − Forecasting the Future of Industry 4.0.* 1st Ed. CRC Press.

Baudin M. and Netland T. (2023) *Introduction to Manufacturing − An Industrial Engineering and Management Perspective.* 1st Ed. Routledge.

Brauer D. and Cesarone J. (2022) *Total Manufacturing Assurance − Controlling Product Quality, Reliability, and Safety.* 2nd Ed. CRC Press.

Cheng F.T. (Editor) (2021) *Industry 4.1: Intelligent Manufacturing with Zero Defects.* Wiley-IEEE Press.

Groover M.P. (2016) *Automation, Production Systems, and Computer-Integrated Manufacturing.* 4th Ed. Pearson Higher Education.

Gupta K. and Salonitis K. (Editors) (2021) *Sustainable Manufacturing.* 1st Ed. Elsevier.

Kalpakjian S. and Schmid S. (2022) *Manufacturing Engineering and Technology in SI Units.* 8th Ed. Pearson.

Liker J.K. (2020) *The Toyota Way, Second Edition: 14 Management Principles from the World's Greatest Manufacturer.* 2nd Ed. McGraw-Hill.

Patel C.D. and chen C.H. (Editors) (2024) *Digital Manufacturing − Key Elements of a Digital Factory.* 1st Ed. Elsevier.

Popkova E.G., Ragulina Y.V. and Bogoviz A.V. (Editors) (2019). *Industry 4.0: Industrial revolution of the 21st century (Vol. 169, p. 249).* Cham: Springer.

Pruncu C.I. and zbitou J. (2023) *Advanced Manufacturing Methods − Smart Processes and Modeling for Optimization*. 1st Ed. CRC Press.

Singh C.D. and kaur H. (Editors) (2023) *Factories of the Future: Technological Advancements in the Manufacturing Industry*. Wiley.

Steenhuis H.J. (2024) *The Business of Additive Manufacturing − 3D Printing and the 4th Industrial Revolution*. 1st Ed. Routledge.

Youssef H.A., El-Hofy H.A. and Ahmed M.H. (2024) *Manufacturing Technology − Materials, Processes, and Equipment.* 2nd Ed. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Additive Manufacturing

Additive Manufacturing Letters

Advances in Industrial and Manufacturing Engineering

Journal of Advanced Manufacturing Systems

Journal of Advanced Manufacturing Technology

Journal of Manufacturing Processes

Journal of Manufacturing Science and Technology

Journal of Manufacturing Systems

Manufacturing Letters

The International Journal of Advanced Manufacturing Technology

Links

This unit links to the following related units:

Unit 5015: Manufacturing Systems Engineering
Unit 5016: Lean Manufacturing
Unit 5018: Sustainability.

Unit 5018: Sustainability

Unit Code: Y/615/1519

Level: 5

Credits: 15

Introduction

Living and working in the 21st century will bring a range of sustainability challenges that our society has not seen before. For many people on our planet key resources such as food, water and energy will be in short supply, whilst the effects of climate change will be felt by everyone.

The Brundtland Commission of the United Nations on 20th March 20th 1987 defined sustainability as: ‘sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs’. Engineers will be in the frontline of the battle to overcome the challenges of creating a sustainable economy, but no single discipline will have the capability to tackle the problems alone. Sustainability is a multidisciplinary challenge, and engineers of the future will have to work collaboratively with a whole range of other stakeholders, such as scientists, politicians and financiers, if they are to be able to produce the practical and technological solutions required within the necessarily urgent time scales.

This unit is designed to support the Professional Engineering and Professional Engineering Management core units at Level 4 and 5. On successful completion of this unit the student with possess a wide range of knowledge and understanding of the issues and topics associated with sustainability and low carbon engineering.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine the nature and scope of the technical challenges of ensuring sustainable development

LO2 Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems

LO3 Evaluate the use of alternative energy generation techniques in relation to their contribution to a low carbon economy

LO4 Analyse a variety of data sources to estimate the carbon footprint of a socio-technical scenario.

Essential Content

LO1 **Determine the nature and scope of the technical challenges of ensuring sustainable development**

The scope and social context of sustainability:

Sustainable development

Brundtland definition

Global demographics, trends and predictions

Population growth

Standard of living, actual and expected

Urbanisation and the balance of urban/rural space

Sustainable design.

Environmental issues:

Climate change, planetary energy balance, carbon cycle science, the 2° C climate change obligation

Carbon capture and sequestration

Pollution, pollution prevention and management

Carbon trading

Eco-systems and habitat.

Resources:

Food, water, energy and raw materials.

LO2 **Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems**

Systems thinking and socio-technical systems:

The politics and economics of sustainability

Kyoto Protocol

UN Climate Change Conference (COP)

European Union Emissions Trading Scheme.

Sustainable infrastructures:

Low carbon transport systems

Sustainable cities

Green building

Power storage and distribution

Sustainable logistics

Waste and recycling.

LO3 **Evaluate the use of alternative energy generation techniques in relationship to their contribution to a low carbon economy**

Alternative energy resources:

Nuclear, solar, wind, tidal and wave, geothermal, biomass and bioenergy

Whole life cycle costing

Precautionary principle.

LO4 **Analyse a variety of data sources to estimate the carbon footprint of a socio-technical scenario.**

Types of carbon footprint:

Organisational

Value chain

Product

Carbon footprint science

Calculation methodologies: direct and indirect

System boundaries

Case study examples.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine the nature and scope of the technical challenges of ensuring sustainable development		
P1 Determine the nature and scope of the technical challenges of ensuring sustainable development, considering environmental, resource and demand issues.	**M1** Review existing sustainable development plans to identify the way technical challenges are met and overcome.	**D1** Critically analyse how the interrelationship between the three key areas of technical challenges can be managed systemically to ensure maximum sustainability.
LO2 Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems		
P2 Articulate the interdisciplinary issues associated with the construction of sustainable infrastructures, with attention to the competing pressures within these infrastructures.	**M2** Analyse how political and economic issues can impact upon technical solutions.	**D2** Critically analyse how a systemic approach can be used to support interdisciplinary collaboration in developing sustainable infrastructures.
LO3 Evaluate the use of alternative energy generation techniques in relation to their contribution to a low carbon economy		
P3 Evaluate the issues that need to be considered when selecting alternative low carbon energy sources.	**M3** Analyse the difficulties in the evaluation and selection of alternative energy generation techniques for a low carbon economy.	**D3** Critically analyse the selection of alternative energy generation techniques for a low carbon economy within the wider socio-technical sustainability agenda.
LO4 Analyse a variety of data sources to estimate the carbon footprint of a socio-technical scenario.		
P4 Evaluate a variety of data sources to estimate the carbon footprint of a number of socio-technical scenarios. **P5** Describe the process of calculating a carbon footprint.	**M4** Apply appropriate data from a range of options to calculate the carbon footprint of a socio-technical scenario.	**D4** Analyse the alternative types and methods available for calculating the carbon footprint of a sociotechnical scenario, and make justified recommendations, selecting a best-fit method for effective comparison of systems.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bakhshi R. B. (2019) *Sustainable Engineering: Principles and Practice*. 3rd Ed. Cambridge University Press.

Berners-Lee, M. (2019) *There Is No Planet B: A Handbook for the Make or Break Years* Cambridge University Press

Berners-Lee, M. (2010) *How Bad Are Bananas?* Profile Books.

Boyle, G. (2012) *Energy Systems and Sustainability: Power for a Sustainable Future*. Oxford University Press.

Everett B., Peake S., and warren J. (2021) *Energy Systems and Sustainability*. 3rd Ed. Oxford University Press.

Fenner, A. and Ainger, C. (2013) *Sustainable Infrastructures: Principles into Practice*. ICE Publishing.

Helm, D. (2015) *The Carbon Crunch: Why we are Getting Climate Change Wrong and How to Fix It*. Yale University Press.

Hone, D. (2014) *Putting the Genie Back: 2˚c Will Be Harder Than We Think*. Whitefox Publishing.

Morris P. and Therivel R. (2009) *Methods of Environmental Impact Assessment*. 3rd Ed. London Routledge.

Websites

http://www.carbontrust.com	Carbon Trust Carbon foot printing (General Reference)
http://www.fern.org/	FERN Trading Carbon How it Works and Why it is Controversial (Ebook)
https://www.populationinstitute.org	Population Institute Demographic Vulnerability report (Report)
http://www.un.org/	United Nations Integrating Population Issues into Sustainable Development (Report)

http://www.unwater.org/	United Nations Water Annual World Water Development Report (Report)
https://sustainabledevelopment.un.org/	United Nations Sustainable Development Knowledge Platform (General Reference)

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 5002: Professional Engineering Management.

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit Code: **H/651/0882**

Level: **5**

Credits: **15**

Introduction

Almost every aspect of our lives relies on electrically powered, electronically controlled machines and devices, many of them digital in format. To properly understand how to make the most efficient use of these devices in a safe and economical way, it is vital to have a thorough knowledge of the underlying principles on which they rely.

This unit builds on the preliminary techniques and skills introduced in *Unit 4019: Electrical, Electronic Principles* and *Unit 4020: Digital Principles*.

The emphasis in this unit will be in developing a structured approach to the analysis of AC single-phase and three-phase powered circuitry. This will help students to arrive at the solution in the most efficient way, with the greatest probability of it being correct. In addition, students will be introduced to the expanding use of computers, using specialised software to solve electrical, electronic, and digital circuits. This will allow students to develop the necessary confidence and competence in the four key areas of mathematical techniques, circuit analysis, circuit simulation and laboratory practice.

Successful completion of this unit will enable students to manage increasingly complex problems and prepare them for the challenge of Level 6 academic programmes.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Solve a range of electrical and electronic problems by applying appropriate circuit theorems and mathematical methods

LO2 Apply appropriate methods to analyse and solve three-phase network problems

LO3 Examine analogue and digital circuits using appropriate laboratory and simulation techniques

LO4 Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions

Essential Content

LO1 **Solve a range of electrical and electronic problems by applying appropriate circuit theorems and mathematical methods**

Formal steady state circuit analysis:

Determinants, mesh analysis and nodal analysis (and their comparison)

Analysis using ideal sources

Application of fundamental electrical circuit theorems (e.g. complex numbers, reactance, impedance, Kirchhoff's laws, Norton and Thevenin's theorems, superposition)

AC and DC analysis similarities and differences.

AC circuit analysis:

Complex notation, polar and Cartesian coordinates, RLC circuits

Advanced use of phasor diagrams

Power: instantaneous power, power factor, apparent power, the power triangle

AC and DC power analysis similarities and differences

AC and DC power applications examples.

LO2 **Apply appropriate methods to analyse and solve three-phase network problems**

Three-phase theory:

Theorems and theoretical aspects of three-phase networks

Application of trigonometric methods to solution of phasor diagrams

Application of complex numbers to represent quantities in AC circuits

Single-phase representation, and power flow analysis

Solution of balanced three-phase circuits

Analysis and comparison of delta and wye configurations

Complex notation applied to three-phase, unbalanced loads, unconnected neutral point

Real power, reactive power, apparent power, power factor correction, and efficiency for three-phase systems

Power measurements and calculations in AC and three-phase systems

Applications of three-phase systems.

LO3 **Examine analogue and digital circuits using appropriate laboratory and simulation techniques**

ECAD:

Use of computer modelling and simulation techniques to analyse and solve electronic, electrical, and digital circuits, such as filters and amplifiers using operational amplifiers and discrete devices; digital logic circuit elements; and simple combination and sequential circuits

Health and safety policies, procedures and regulations, risk assessment and mitigation, workplace considerations (i.e., devices and operating personnel)

Use of electrical and electronic instrumentation devices (e.g. multimeter, signal generator, power supply, oscilloscope, etc.) to take measurements of various circuits

Input/Output analysis for electronic, electrical, and digital circuits including combinations of systems

DC-AC conversion with example practical applications.

LO4 **Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions**

Non-linear circuits:

Characteristics of linear and non-linear circuits (e.g. I-V relationships, component behaviour, hysteresis, memory effects, etc.), mathematical modelling of a number of semiconductor devices, including diodes, bipolar and Field Effect Transistors and how this can be used to predict their ‘real’ behaviour in practice

Mathematically modelling the behaviour of semiconductor diodes, bipolar transistors, and Field Effect Transistors

Non-linear behaviour of operational amplifiers.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Solve a range of electrical and electronic problems by applying appropriate circuit theorems and mathematical methods		
P1 Solve electrical AC circuit problems by applying the appropriate theorems and methods.	**M1** Analyse behaviour of AC circuits in terms of electrical power and performance.	**D1** Analyse the performance of AC circuits and their application, with justification of the theorems and methods used, including mathematical methods and/or simulation.
LO2 Apply appropriate methods to analyse and solve three-phase network problems		
P2 Apply suitable theories and methods to solve three-phase network problems for a given industry context.	**M2** Analyse how to synthesise three-phase systems in terms of electrical power, efficiency, and performance.	**D2** Critically analyse the performance of three-phase circuits and their application, with justification of the methods used.
LO3 Examine analogue and digital circuits using appropriate laboratory and simulation techniques.		
P3 Examine the performance of analogue and digital circuits by using the appropriate laboratory and simulation techniques.	**M3** Analyse analogue and digital circuits behaviour using the appropriate laboratory and simulation techniques.	**D3** Evaluate the operation of analogue and digital circuits by comparing their predicted behaviour with simulated, theoretical and practical results.
LO4 Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions		
P4 Explain the characteristics of non-linear circuits and how their behaviour differs in practice with 'ideal' devices.	**M4** Investigate a variety of non-linear circuits by calculating and/or simulating the effects of non-linear behaviour in a number of differing circuits.	**D4** Evaluate the application of theory, simulation and practical investigation of a number of circuits, using non-linear circuit theory.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bird J. (2013) *Electrical Circuit Theory and Technology*. Routledge.

Boylestad R.L. (2023) *Introductory Circuit Analysis.* Global Edition. 14th Ed. Pearson.

Boylestad R.L., and Nashelsky L. (2013) *Digital fundamentals: A systems approach*. Pearson.

Fleckenstein J.E. (2020) *Three-Phase Electrical Power*. CRC Press.

Emery R.C. (2020) *Digital Circuits: Logic and Design.* 1st Ed. CRC Press.

Hambley A.R. (2018) *Electrical Engineering: Principles and Applications*. Global Edition. 7th Ed. Pearson.

Hughes E. et al. (2012) *Electrical and Electronic Technology*. Pearson.

Mohindru P. and Mohindru P. (2022) *Electronic Circuit Analysis using LTSpice XVII Simulator: A Practical Guide for Beginners*. 1st Ed. CRC Press.

Rehg J.A. and Sartori G.J. (2005) *Industrial Electronics*. Prentice-Hall.

Robertson C.R. (2008) *Fundamental Electrical and Electronic Principles*. 3rd edition, Newnes.

Wilamowski B.M. and Irwin J.D. (2011) *The Industrial Electronic Handbook: Fundamentals of Industrial Electronics*. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advances in Electrical Engineering, Electronics and Energy

Electronic Letters

Electronics World Magazine

Everyday Practical Electronics Magazine

IEEE Transactions on Circuits and Systems

IEEE Transactions on Industrial Electronics

IEEE Transactions on Power Electronics

Industrial Economics Society

Journal of Electrical and Electronic Engineering

New Electronics Digital Magazine

Links

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4020: Digital Principles.

Unit 5020: Utilisation of Electrical Power

Unit Code:	**K/651/0884**
Level:	**5**
Credits:	**15**

Introduction

The supply, processing and usage of electrical energy is a leading preoccupation around the world today, with significant technical, economic, environmental, and societal implications. Engineers must engage seriously with this issue and need to be aware of the real and practical impact of their decisions.

The aim of this unit is to develop students' understanding of electrical power systems and power distribution, giving consideration to the advantages and disadvantages of alternative power sources.

Students will learn about the construction and characteristics of power transmission and distribution systems, including the interconnections of systems and their necessary protection. Students will also consider the economics of components, power systems and alternative energy sources, in line with emerging developments within the energy sector.

On successful completion of this unit students will be able to explain the demands, sources and construction of electrical power generation and distribution systems, review the interconnections of power systems and their necessary protection, identify the requirement for engineering activity and describe new and emerging methods to optimise energy usage.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine the demands, sources, construction of electrical power generation and distribution systems

LO2 Explore the interconnections of power systems, their protection, the critical processes, the effects of failure and the importance of electrical safety

LO3 Evaluate the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources

LO4 Discuss new and emerging methods to optimise energy usage, conversion, and storage techniques.

Essential Content

LO1 **Examine the demands, sources, construction of electrical power generation and distribution systems**

Demands of a power generation and transmission system:

Total power demands of a country over a period of a working week, identifying average, minimum and maximum demands

Overall annual energy consumption of domestic, industrial, transport and other systems, identifying and quantifying energy losses

Extent of delivered energy that is in the form of electrical energy

Comparison between the demands of a G20 industrial economy with that of a developing region economy; analysis of the trends of energy supply and demand data to predict future energy requirements and budgets; contribution to the energy supplied by each of the significant primary sources of energy of a defined country. Influence of long-term governmental policy on managing the energy budget; Discuss in groups the trends in electrical power generation and distribution systems.

LO2 **Explore the interconnections of power systems, their protection, the critical processes, the effects of failure and the importance of electrical safety**

Construction of power generation and transmission systems:

Comparisons between the distribution of power using DC and single-phase and polyphase AC transmission systems, amplitude and phase of voltages and currents in three-phase systems with resistive and complex loads

Power factor and power measurement techniques of AC systems, including identification of a range of loads and their respective power factors, consequences of loads with poor power factor and the advantages of applying power factor corrections; Calculation of power factor correction components

recognition of the effects of perturbations and harmonics within AC systems and describing methods to measure and reduce harmonics; Protecting the power distribution network from the effects of overload or damage, and identification of the requirements of a robust protection system; Evaluation of the impedance of an AC transmission line, its power losses and its effect on the power delivered to a load

Review safety procedures associated with power networks and techniques for the safe measurement of system parameters

Analysis of a power network with multiple generators, transmission lines and loads using power systems simulation software.

LO3 **Evaluate the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources**

Sources of electrical energy:

Efficiency, costs, security, and environmental implications of energy production using coal, oil and natural gas; Scope of 'renewable' in relation to sources of energy

Evaluation of the efficiency, costs, security, and environmental implications of energy production using renewable sources of mechanical kinetic energy, including wave, tidal, large- and small-scale hydro and wind

Evaluate the efficiency, costs, security, and environmental implications of energy production using solar heating, solar photovoltaics, biomass, fuel cells and geothermal techniques. Current state of research into nuclear, fusion and fission energy and other novel forms of energy.

LO4 **Discuss new and emerging methods to optimise energy usage, conversion, and storage techniques**

Techniques for optimising electrical energy generation:

Techniques for optimising the generation of electricity in power stations and small-scale generators by using varied and distributed generation systems and managing the generation of power

Techniques for optimising energy usage and conversion:

Technologies and techniques for improving the efficiency or reducing the energy consumption of equipment in common use, including lighting, heating, transport, and industrial processes.

Energy storage techniques:

The need for energy storage techniques as part of an energy management programme, short-term and long-term energy storage techniques and their connection to the power grid, including, hydro, battery, super capacitor, flywheel and thermal

Emerging battery technologies and battery management techniques.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the demands, sources, construction of electrical power generation and distribution systems		
P1 Examine the key aspects of a country's energy supply, demand, and losses to create a balanced energy budget for the example.	**M1** Apply reliable data to quantify past and current energy trends and predict future trends, having first established the reliability of data from a variety of sources.	**D1** Critically evaluate government policies for managing energy budgets in the long term, making justified recommendations.
LO2 Explore the interconnections of power systems, their protection, the critical processes, the effects of failure and the importance of electrical safety		
P2 Explore the key aspects of three-phase power systems using distributed generators and loads and protection. **P3** Perform calculations and simulations on example systems, showing power losses and the advantages of applying power factor correction.	**M2** Analyse and interpret the results of computer-based simulations of power networks.	**D2** Critically evaluate the technologies for maintaining a high-quality electrical supply to customers, and demonstrate the advantages of applying these by computer simulation or otherwise.
LO3 Evaluate the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources		
P4 Evaluate the technology of renewable sources of energy, taking into account efficiency, costs, security and environmental implications.	**M3** Critically evaluate the application of renewable energy sources to meet existing demands, taking into account efficiency, costs, security and environmental implications.	**D3** Propose novel forms of energy generation using recently published research, taking into account efficiency, costs, security and environmental implications.
LO4 Discuss new and emerging methods to optimise energy usage, conversion, and storage techniques		
P5 Discuss representative examples of existing and emerging methods of energy optimisation.	**M4** Evaluate the environmental effects of applying known energy optimisation techniques.	**D4** Conceptualise novel forms of energy optimisation and efficiency and their applications, using recent research publications.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Alassouli H.M. (2021) *Lecture Notes of Generation of Electrical Power Course*.

Alassouli H.M. (2018) *Electrical Power Distribution: Lecture Notes for Electrical Power Distribution Course* − Softcover. Createspace Independent Publishing Platform

Meier A.V. (2006) *Electric Power Systems: A Conceptual Introduction*. 1st Ed. John Wiley & Sons.

Glover J.D., Sarma M.S., and Overbye T.J. (2017) *Power System Analysis and Design.* 6th Ed. Cengage Learning.

Pabla A.S. (2014) *Power System Engineering.* 1st Ed. BS Publications.

Gonen T. (2007) *Electric Power Transmission System Engineering: Analysis and Design*. 2nd Ed. CRC Press.

Gonen T. (2020) *Electric Power Distribution Engineering*. 3rd Ed. CRC Press.

Mohan N. (2012) *Electric Power Systems: A First Course.* 1st Ed. John Wiley & Sons.

Grainger J. and Stevenson Jr. W.D. (1994) *Power System Analysis.* 1st Ed. McGraw-Hill.

Mohan N., Undeland T.M., and Robbins W.P. (2002) *Power Electronics: Converters, Applications, and Design.* 3rd Ed. John Wiley & Sons.

Ram B. and Vishwakarma D.N. (2018) *Power System Protection and Switchgear.* 2nd Ed. McGraw-Hill Education.

Del Toro V. (1992) *Electric Machines and Power Systems: Volume I − Electric Machines*. 1st Ed. Schaum's Outline Series.

Cooper I. (Editor) (2022) *Electrical Power Systems: Engineering Essentials* (Hardback). Murphy & Moore Publishing.

Gupta O.H., Sood V.K., and Malik O.P. (Editors) (2023*) Recent Advances in Power Systems: Select Proceedings of EPREC-2021 − Lecture Notes in Electrical Engineering 812* (Paperback). Springer Verlag.

Silver M. (Editor) (2017) *Electrical Power Transmission and Distribution* (Hardback). NY Research Press.

Taylor W.T. (2023) Electric *Power Systems: A Practical Treatment of the Main Conditions, Problems, Facts and Principles in the Installation and Operation of Modern Electric Power Systems, for System Operators, General Electrical Engineers and Students* (Hardback). Legare Street Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Electrical Power Systems Research

Energy Storage

Energy Storage Journal

Electric Power Components and Systems

Energy Procedia

IEEE Industry Applications Magazine

IEEE Transactions on Industrial Electronics

IEEE Transactions on Industrial Informatics

IEEE Transactions on Power Electronics

International Journal of Electrical Power & Energy Systems

Sustainable Cities and Society

Links

This unit links to the following related units:

Unit 5008: Distributed Control Systems

Unit 5011: Industrial Power, Electronics and Storage.

Unit 5021: Further Control Systems Engineering

Unit Code: M/651/0886

Level: 5

Credits: 15

Introduction

Control engineering is usually implemented at the top level of large projects, determining the engineering system performance specifications, the required interfaces, and hardware and software requirements. In most industries, stricter requirements for product quality, energy efficiency, pollution level controls and the general drive for improved performance, place tighter limits on control systems.

A reliable and high-performance control system depends a great deal upon accurate measurements obtained from a range of transducers, mechanical, electrical, optical and, in some cases, chemical. The information provided is often converted into digital signals on which the control system acts to maintain optimum performance of the process.

The aim of this unit is to provide the student with the further knowledge of the principles of control systems and to advance understanding of how these principles can be used to model and analyse simple control systems found in industry. The study of control engineering is essential for most engineering disciplines, including electrical, mechanical, chemical, aerospace, and manufacturing.

On successful completion of this unit students will be able to devise a typical three-term controller for optimum performance, grasp several control techniques and how these can be used to predict and control the behaviour of a range of engineering processes in a practical way.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain concepts and contemporary applications of control systems

LO2 Analyse the elements of a high-level control system and its model development

LO3 Evaluate the structure and behaviour of high-level control systems

LO4 Examine the application of control parameters to produce optimum performance of a control system.

Essential Content

LO1 **Explain concepts and contemporary applications of control systems**

Background, terminology, underpinning principles, and system basics:

Control system terminology and identification, including plant, process, system, disturbances, inputs and outputs, initial time, additivity, homogeneity, linearity and stability

Control systems properties and configurations, classification and performance criteria of control systems

Block diagram representation of control systems and their relevance in industrial application

Principles of Transfer Function (TF) for open and closed loop systems, use of current computational tools for use in control systems (e.g., MATLAB, Simulink, LabVIEW)

Latest methods of using data for control systems and applications − data collection systems, data formats, documentation control processes and procedures (e.g., location, access, authorisation)

Control systems and Industry 4.0 – relevance and impact on organisations.

LO2 **Analyse the elements of a high-level control system and its model development**

Developing system applications:

Simple mathematical models of electrical, mechanical, and electro-mechanical systems

Block diagram representation of simple control systems

Introduction of Laplace transform and its properties, simple first and second order systems and their dynamic responses

Modelling and simulation of simple first and second order control system using current computational tool (e.g., MATLAB, Simulink, LabVIEW).

LO3 **Evaluate the structure and behaviour of high-level control systems**

System behaviour:

Transient and steady behaviour of simple open loop and closed loop control systems in response to a unit step input

Practical closed loop control systems and the effect of external disturbances

Poles and zeros and their role in the stability of control systems, steady-state error. Applicability of Routh-Hurwitz stability criterion

Use of current computational tools (e.g., MATLAB, Simulink, LabVIEW) to model, simulate and analyse the dynamic behaviour of simple open and closed loop control systems.

LO4 **Examine the application of control parameters to produce optimum performance of a control system**

Control parameters and optimum performance:

Introduction to the three-term PID controller, the role of a Proportional controller (P), Integral controller (I) and the Derivative controller (D)

General block diagram representation and analysis, effects of each term, P-I-D, control applied to first and second order systems

Simple closed loop analysis of the different combinations of the terms in PID controllers, effect of the three terms on disturbance signals and an introduction to simple PID controller tuning methods

Modelling and simulation using current computational tools (e.g., MATLAB, Simulink, LabVIEW) to analyse the effects of each P-I-D term, individually and in combination on a control system

Overview of developments and future applications of using AI in supporting adaptive/self-learning control systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain concepts and contemporary applications of control systems		
P1 Explain a control system using block diagram representation and simplifications. **P2** Conceptualise a model of an open and closed loop control system using simulation.	**M1** Apply advanced modelling techniques to develop the block diagram of a closed loop system for the position control of DC motor using a PID controller.	**D1** Evaluate the performance of a PID controller for position control of a DC motor.
LO2 Analyse the elements of a high-level control system and its model development		
P3 Analyse the main building blocks for high-level electrical and mechanical control systems. **P4** Apply Laplace transforms to mechanical or electrical control problems.	**M2** Analyse Electrical, Mechanical and Electro-Mechanical control systems using appropriate mathematical models and simulation.	**D2** Critically evaluate complex electrical, mechanical and electromechanical control systems using mathematical models, control engineering methods and simulation.

Pass	Merit	Distinction
LO3 Evaluate the structure and behaviour of high-level control systems		
P5 Analyse the behaviour and response of first and second order systems. **P6** Evaluate the external effects on the stability of PID control systems and the techniques used to maintain stability in these systems.	**M4** Use analytical techniques to analyse how the stability of a dynamic PID control system.	**D3** Critically review the performance of a second-order electromechanical control system when subjected to external disturbances.
LO4 Examine the application of control parameters to produce optimum performance of a control system		
P7 Examine the role and implementation of the PID controllers in a simple electrical, mechanical, and/or electro-mechanical control systems. **P8** Synthesize the effects of the P, I, and D parameters on the dynamic responses of the first and second order systems.	**M5** Analyse dynamic responses of PID controllers in terms of position control, tracking and disturbance rejection.	**D4** Evaluate the behaviour of a second-order control system when PID terms are changed individually and in combination, using modelling and computer simulation techniques.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bolton W. (2021) *Instrumentation and Control Systems*. 3rd Ed. Elsevier.

Dabney J.B. and Harman T.L. (2003) *Mastering Simulink*. Prentice Hall.

Dorf R.C. and Bishop R.H. (2022) *Modern Control Systems*. 14th Ed. Pearson.

Essic J. (2018) *Hands-On Introduction to LabVIEW for Scientists and Engineers*. 4th Ed. Oxford University Press.

Iqbal K. (2020) *A First Course in Control System Design.* 2nd Ed. River Publishers.

Kondratenko Y.P, Kuntsevich V.M., Chikrii A.A. and Gubarev V.F. (2021) *Advanced Control Systems – Theory and Applications.* 1st Ed. River Publishers.

Moore H. (2019) *MATLAB for engineers.* 5th Ed. Pearson.

Nagrath I.J. (2022) *Control Systems Engineering.* 7th Ed. New Age International Publishers.

Nise N.S. (2011) *Control Systems Engineering*. 6th Ed. John Wiley & Sons.

Sarangapani J. and Xu H. (2021) *Optimal Networked Control Systems with MATLAB.* CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Frontiers in Control Engineering

IEEE Open Journal of Control Systems

IFAC Journal of Systems and Control

Journal of Control Science and Engineering

Journal of Dynamic and Control Systems

Journal of Process Control.

Links

This unit links to the following related units:

Unit 4016: Instrumentation and Control Systems

Unit 5008: Distributed Control Systems.

Unit 5022: Industrial Services

Unit Code: K/615/1525

Level: 5

Credits: 15

Introduction

Behind the scenes in many modern-day manufacturing facilities there lies a complex system of services that powers production, both day and night. The underlying aim of this unit is to enhance the students' understanding of the electrical supply systems, industrial air compressors, steam services, refrigeration systems and heat pumps that are used in an array of industrial engineering environments.

This broad-based methodology reflects the fact that operations engineering encompasses many disciplines and, as such, engineers must be conversant in the wide scope of service provision. The intention is to encourage students to develop a holistic approach to the design, operation, installation and maintenance of both industrial services and operating equipment.

The student will be introduced to the fundamental principles of electrical power and lighting systems, the rudiments of industrial compressed air systems, the provision of steam for both power generation and process plant, and the applications and precepts of refrigeration plant and heat pumps.

On successful completion of this unit students will be able to manage and maintain a wide range of commonly encountered industrial systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Apply the operating principles of electrical power and lighting systems

LO2 Investigate the applications and efficiency of industrial compressors

LO3 Discuss provision of steam services for process and power use

LO4 Review industrial refrigeration and heat pump systems.

Essential Content

LO1 Apply the operating principles of electrical power and lighting systems

Electrical power:

Construction, starting and speed control of polyphase induction motors

Three-phase transformers: construction, clock number and group, parallel operation

Electrical distribution: power system topologies, efficiency, power factor causes and correction, effect on cost of supplies, circuit protection.

Lighting systems:

Lighting fundamentals: SI units, energy efficient circuit design and layout.

LO2 Investigate the applications and efficiency of industrial compressors

Industrial compressors:

Types and applications of industrial compressors

Role of intercoolers, dryers and air receivers

Efficiency and performance of air compressors

Hazards and faults: safety consideration and associated legislation.

LO3 Discuss the provision of steam services for process and power use

Steam power plant:

Use of tables and charts to analyse wet and dry saturated steam

Circuit diagrams showing steam raising plant

Process steam: enthalpy of evaporation, available energy

Overall plant efficiencies for process

Power steam: superheated steam, turbine efficiency, Rankine cycle, cooling towers

Overall plant efficiency for power

Efficiencies and improvements.

LO4 **Review industrial refrigeration and heat pump systems.**

Heat pumps and refrigeration:

Typical industrial heat pump and refrigeration systems

Application of the second law of thermodynamics

Reversed heat engines: reversed Carnot cycle

Vapour compression cycle

Refrigerant fluids: environmental impact

Refrigeration tables and charts (p-h diagrams)

Coefficient of performance for heat pumps and refrigerators.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply the operating principles of electrical power and lighting systems		**D1** Analyse the approaches available for reducing electrical energy consumption/costs in an industrial production facility.
P1 Illustrate the construction and modes of connection of three-phase transformers. **P2** Discuss the applications and operating characteristics of polyphase induction motors. **P3** Apply the principles of good lighting design to produce a lighting scheme for a given application.	**M1** Compare the economics of single-phase and three-phase distribution, and assess the methods of speed control applied to polyphase induction motors.	
LO2 Investigate the applications and efficiency of industrial compressors		**D2** Stating any assumptions, provide an explanatory derivation of the volumetric efficiency formula for a reciprocating compressor.
P4 Compare three types of industrial compressor and identify justifiable applications for each. **P5** Review potential industrial compressor faults and hazards. **P6** Determine the performance characteristics of an industrial compressor.	**M2** Calculate the isothermal and polytropic work of a reciprocating compressor and thus deduce the isothermal efficiency. Explain any discrepancies.	

Pass	Merit	Distinction
LO3 Discuss the provision of steam services for process and power use		
P7 Demonstrate the need for superheated steam in a power generating plant. **P8** Discuss the requirements for process steam and determine overall plant efficiencies for steam process and power systems.	**M3** Illustrate why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world.	**D3** Evaluate the modifications made to the basic steam raising systems to improve their overall efficiency.
LO4 Review industrial refrigeration and heat pump systems.		
P9 Discuss the operating principles of both heat pumps and industrial refrigeration systems. **P10** Calculate COP, heating effect and refrigeration effect of reversed heat engines, making use of refrigeration tables and pressure/enthalpy charts.	**M4** Assess the limiting factors that impact on the economics of heat pumps. **M5** Discuss the apparent contradiction between refrigeration cycles and the second law.	**D4** Conduct a cost-benefit analysis on the installation of a ground source heat pump on a smallholding. Present your findings in the form of academic poster/ presentation.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson A. (2020) *Wind Turbines: Theory and Practice*. Cambridge University Press.

Cibse. (2002) *Code for lighting*. Butterworth-Heinemann.

Dunn, D. (2001) *Fundamental Engineering Thermodynamics*. Longman.

Eastop, T.D. and McConkey, A. (1996) *Applied Thermodynamics for Engineering Technologists*. 5th Ed. Prentice Hall.

Hughes, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications.* 4th Ed. Newnes.

Giampaolo T. (2024) *Compressor Handbook: Principles and Practice.* 2nd Ed. Routledge.

Rogers, G.F.C. and Mayhew, Y.R. (1994) *Thermodynamic and Transport Properties of Fluids: S. I. Units*. 5th Ed. Wiley-Blackwell.

Melkebeek, J.A. (2018) *Electrical Machines and Drives.* Springer.

Websites

http://www.freestudy.co.uk/	Free Study (Tutorials)

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 5005: Further Thermodynamics

Unit 5023: Thermofluids.

Unit 5023: Thermofluids

Unit Code: R/651/0887

Level: 5

Credits: 15

Introduction

In everyday life, you are never too far away from some system or device that relies on both fluid mechanics and thermodynamics. From the water circulating in your home central heating radiators to the hydraulic door closer to the back of a fire door, the presence of thermofluids is constantly around us.

This unit aims to provide a rational understanding of functional thermodynamics and fluid mechanics in common industrial applications. The unit promotes a problem-based approach to solving realistic work-related quandaries such as steam plant efficiency and fluid flow capacities, and complements other units such as *Units 4011, 4013,* and *5005*.

Students will examine fundamental thermodynamic principles, steam and gas turbine systems, and viscosity in fluids, along with static and dynamic fluid systems. Each element of the unit will identify a variety of engineering challenges and assess how problems are overcome in real-life industrial situations.

Students will develop their perceptions of industrial thermodynamic systems, particularly those involving steam and gas turbine power. In addition, they will consider the impact of energy transfer in engineering applications along with the characteristics of fluid flow in piping systems and numerous hydraulic devices, all of which are prevalent in typical manufacturing and process facilities.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate industrial thermodynamic systems and their properties

LO2 Examine the operation of practical steam and gas turbine plants

LO3 Illustrate the effects of viscosity in fluids

LO4 Analyse fluid systems and hydraulic machines.

Essential Content

LO1 Evaluate industrial thermodynamic systems and their properties

Thermodynamic systems:

Power generation plant

Application of the first law of thermodynamics

Analysis of Non-Flow Energy Equation (NFEE) and Steady Flow Energy Equation (SFEE) systems

Application of thermodynamic property tables

Energy transfer systems employing polytropic processes (isothermal, adiabatic, and isentropic)

Pressure/volume diagrams and the concept of work done: use of conventions

The application of the Gas Laws and polytropic laws for vapours and gases

Heat transfer theory and fundamentals

One-dimensional conduction and thermal resistance

Application of problem-solving tools in the context of thermodynamic system investigations e.g. root cause analysis (RCA), process failure modes effects analysis (PFMEA), fishbone, practical problem solving (PPS), advanced product quality planning (APQP)

Health and safety within the context, including risk awareness and compliance.

LO2 Examine the operation of practical steam and gas turbine plants

Steam and gas turbine plant:

Second Law of Thermodynamics and entropy

Heat Engine, Heat pump, and Carnot cycle

Entropy property and T-s diagram

Principles of operation of steam and gas turbine plants

Use of property diagrams to analyse plant

Characteristics of steam/gas turbine plant as used in energy supply

Energy-saving options adopted on steam plants operating on modified Rankine cycle

Performance characteristics of steam and gas power plant

Cycle efficiencies: turbine isentropic efficiencies and overall relative efficiency

Use of various problem-solving tools in the context of steam and gas turbine plants, with industry scenarios and real-world case studies.

LO3 **Illustrate the effects of viscosity in fluids**

Viscosity in fluids:

Viscosity: shear stress, shear rate, dynamic viscosity, kinematic viscosity

Viscosity measurement: operating principles of viscosity measuring devices e.g., falling sphere, U-tube, rotational and orifice viscometers (such as Redwood)

Newtonian fluids and non-Newtonian fluids: pseudoplastic, Bingham plastic, Casson plastic, and dilatant fluids

Latest trends and applications of viscous fluids.

LO4 **Analyse fluid systems and hydraulic machines**

Fluid systems:

Characteristics of fluid flow: laminar and turbulent flow, Reynolds number

Friction factors: relative roughness of pipe, use of Moody diagrams

Head losses across various industrial pipe fittings and valves, use of Bernoulli's Equation and Darcy's Formula

External incompressible flow and boundary layer

Boundary layer development on a flat surface

Separation and Wake

Aerodynamic forces: lift and drag

Hydraulic machines:

Turbines: Pelton wheel, Kaplan turbine, Francis wheel

Pumps: centrifugal, reciprocating.

Analysis of systems:

Dimensional analysis: verification of equations for torque, power, and flow rate

Application of dimensional analysis to determine the characteristics of a scale model

Use of Buckingham Pi Theorem

Discussion of dimensionless numbers: Reynold, Mach, Froude, Prandtl, and Nusselt numbers.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate industrial thermodynamic systems and their properties		
P1 Evaluate the operation of industrial thermodynamic systems and their properties. **P2** Describe the application of the first law of thermodynamics to industrial systems. **P3** Apply first law analysis for a process of ideal gas.	**M1** Analyse the rate of heat transfer through a composite wall.	**D1** Critically evaluate thermodynamic processes by using non-flow energy equation (NFEE) or steady flow energy equation (SFEE) systems with thermodynamic property tables.
LO2 Examine the operation of practical steam and gas turbine plants		
P4 Examine the principles of operation of steam turbine plant. **P5** Calculate overall steam turbine plant efficiencies by the use of charts and/or tables. **P6** Discuss the principles of operation of gas turbine plants.	**M2** Justify why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world.	**D2** Evaluate the modifications made to the basic Rankine cycle to improve the overall efficiency of steam power plants.
LO3 Illustrate the effects of viscosity in fluids		
P7 Illustrate the properties of viscosity in fluids. **P8** Explore three viscosity measurement techniques.	**M3** Evaluate the effects of shear force on Newtonian and non-Newtonian fluids.	**D3** Compare the results of a viscosity test on a Newtonian fluid with those given on a data sheet and explain any discrepancies.
LO4 Analyse fluid systems and hydraulic machines		
P9 Analyse the characteristics of fluid flow in industrial piping systems. **P10** Discuss the operational aspects of hydraulic machines. **P11** Apply dimensional analysis to fluid flow.	**M4** Review the significance of the Reynolds number on fluid flow in a given system.	**D4** Evaluate the use of dimensionless analysis using the Buckingham Pi Theorem for a given industrial application.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Baskharone E. A. (2012) *Thermal Science: Essentials of Thermodynamics, Fluid Mechanics, and Heat Transfer*. McGraw Hill.

Bejan A. (2016) *Advanced Engineering Thermodynamics.* John Wiley & Sons, Inc.

Borgnakke C. and Sonntag R. (2022) *Fundamental of Thermodynamics.* 10h Ed. Wiley

Cengel Y. (2020) *Heat and Mass Transfer: Fundamentals and Applications*. 6th Ed. McGraw Hill.

Cengel Y. (2019) *Thermodynamics: An Engineering Approach Si*. 9th Ed. McGraw Hill.

Cengel Y.A. and Cimbala J.M. (2013) *Fluid Mechanics Fundamentals and Applications (Mechanical Engineering)* Hardcover. McGraw-Hill.

Massey B.S. and Ward-Smith J. (2011) *Mechanics of Fluids.* 9th Ed. Oxford: Spon Press.

Revankar S., Sen S. and Sahu D. (Editors) (2021) *Proceedings of International Conference on Thermofluids KIIT Thermo 2020*. Springer.

Trachenko K. (2023) *Theory of Liquids: From Excitations to Thermodynamics* (Hardback). Cambridge University Press.

White F. and Xu H. (2021) *Fluid Mechanics.* 9th Ed McGraw Hill.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Annual Review of Fluid Mechanics

Experimental Thermal and Fluid Science

International Journal of Thermofluids

International Journal of Thermofluid Science and Technology

ISME Journal of Thermofluids

Journal of Fluid Mechanics

International Journal of Heat and Fluid Flow

Journal of Fluids Engineering

Links

This unit links to the following related units:

Unit 4011: Fluid Mechanics

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit 5005: Further Thermodynamics.

Unit 5024: Emerging Semiconductor Technologies

Unit Code: Y/618/1765

Level: 5

Credits: 15

Introduction

The digital economy, Big Data and the Internet of Things have been made possible by the developments of semiconductor devices and materials. Without the ability to mass produce complex, reliable, cheap electronic devices our world would look hugely different. This unit looks at the emerging semiconductor technologies that are improving the current methods and processes to increase efficiency, effectiveness and meet new and exciting demands. The semiconductor industry is a dynamic marketplace and to maintain competitive advantage within the field requires each segment to invest in research and development to be able to produce the next generation devices.

There are very few industrial, medical, automotive, and commercial applications that do not use semiconductor devices in some form or other. New requirements and demands are constantly appearing, and this unit will investigate how new techniques and materials in the manufacturing sector can meet these needs as well as identifying the best solutions for customers.

On successful completion of this unit students will be able to adapt latest trends in semiconductor industry in proposing solutions to complex manufacturing problems through improved methods and processes.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate the properties of emerging semiconductor materials

LO2 Research new trends and applications for emerging semiconductor technologies

LO3 Analyse the requirements and equipment used in emerging semiconductor technologies

LO4 Evaluate the commercial viability of emerging semiconductor technologies.

Essential Content

LO1 **Investigate the properties of emerging semiconductor materials**

Current semiconductor materials and their limitations:

Materials, e.g. silicon, germanium, gallium arsenide

Donor and acceptor materials, e.g. boron, antimony, phosphorous, indium, gallium, arsenic, and aluminium

Physical characteristics, thermal conductivity, e.g. internal noise, electrical limitations (Voltage (V), Current (I), Power (P)), bandwidth, high speed, memory capacity (density) magnetic sensitivity, electrostatic discharge (ESD), and Moore's Law.

Emerging semiconductor materials and their characteristics:

Emerging semiconductor materials

New materials, including enhancements to existing ones, e.g. silicon carbide, gallium manganese arsenide, copper indium gallium selenide, molybdenum disulphide, and bismuth telluride

Compound semiconductors

Properties of new materials.

LO2 **Research new trends and applications for emerging semiconductor technologies**

Characteristics of next generation semiconductor devices:

Research the new materials and assess their suitability and limitations for enhancing current applications, e.g., silicon carbide, compound semiconductors, gallium manganese arsenide, copper indium gallium selenide, molybdenum disulphide bismuth telluride

Health and safety aspects in using these materials

Use of new properties of these materials to enhance and improve current performance in existing areas in generic sector areas; e.g., computing, data, automobile, mobile communications, medical.

LO3 **Analyse the requirements and equipment used in emerging semiconductor technologies**

Processing technologies needed to handle emerging semiconductor materials:

Developing trends in the semiconductor processing industry; e.g., technologies used to process silicon carbide with silicon to produce compound semiconductors

Photolithographic techniques to maximise the area used on the wafer and reduce the dimensions of interconnections

Deposition techniques to transfer donor material onto wafers, such as Atomic Layer Deposition (ALD) and Radio Frequency (RF) magneton sputtering

Increasing placement accuracy – active alignment techniques

New base materials for building and growing semiconductors on ceramic/Teflon/diamond substrates

Multi-chip modules and System in Package applications

Modification of electrical properties on chips

Packaging, flex circuits, stacked dies, and Flip chip/Ball Grid Array (BGA) chip developments.

LO4 **Evaluate the commercial viability of emerging semiconductor technologies.**

The global market place:

Changing markets, design and manufacturing sectors. Growth in demand. Competition. Life cycle. Intellectual Property Rights (IPR). General trends computing; communication, data. National and international supply chains and logistics. Innovation, enterprise and skill development

Commercial awareness of trends and global investment in the semiconductor market.

Emerging and developing markets:

New and innovative areas for commercial development aided by emerging semiconductor devices, e.g., Big Data Analytics, Internet of Things (IoT), entertainment, leisure, artificial intelligence (AI), finance, voting applications

Medical implants, research, testing, and health monitoring

Bio-engineering

Super miniaturisation, e.g., gaming, mobile phones

Agriculture (food production)

Global warming

Automatic transportation systems (cars, railway, aviation, shipping).
Space exploration

Automatic control of services to improve battery efficiency in electric cars, automobile charging of batteries, distribution and storage control of wind and solar power sources

Military, security, and tracking applications

Safety and reducing risk.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the properties of emerging semiconductor materials		
P1 Review the properties of a range of emerging semiconductor materials.	**M1** Compare the characteristics of a silicon PN power diode when compared to those of silicon carbide.	**D1** Evaluate the characteristics of compound silicon devices
LO2 Research new trends and applications for emerging semiconductor technologies		
P2 Discuss how areas such as medicine and automotive engineering may create new demands and opportunities in the semiconductor industry.	**M2** Assess suitability and limitations of different types of semiconductors in emerging application areas.	**D2** Research into how the developing needs of industry and commerce inform and drive the development of new semiconductor devices.
LO3 Analyse the requirements and equipment used in emerging semiconductor technologies		
P3 Describe how photolithographic techniques have been developed to meet the demands of accuracy and increase density of devices on a chip. **P4** Discuss the methods used for packaging individual silicon dies for use on a flex circuit board and a System in Package application.	**M3** Investigate the methods used to grow semiconductor circuits on different substrate materials.	**D3** Evaluate the techniques used to process silicon carbide with silicon to produce a compound semiconductor.
LO4 Evaluate the commercial viability of emerging semiconductor technologies.		
P5 Investigate the current market demand for semiconductor devices.	**M4** Evaluate how the semiconductor industry gathers information on emerging needs from different industrial sectors- e.g. automotive, medical, gaming, and mobile phone.	**D4** Analyse how the semiconductor industry manages the life cycle of products.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson R. L. and Anderson L. (2018) *Fundamentals of Semiconductor Devices.* 2nd Ed. Mc Graw Hill.

Dugaev V. and Litvinov V. (2021) *Modern Semiconductor Physics and Device Applications*. CRC Press.

Evstigneev M. (2022) *Introduction to Semiconductor Physics and Devices*. Springer.

Geng H. (2017) *Semiconductor Manufacturing Handbook*, Second Edition. McGraw Hill Professional.

Hughes E., Hiley J., Brown K. and McKenzie-Smith I. (2012) *Electrical and Electronic Technology*. Pearson.

May G. and Spanos C. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. John Wiley & Sons, Inc.

Websites

semiconductors.org	Semiconductor Industry Association (General reference)
advancedenergy.com	Trends impacting the semiconductor industry in the next three years (General reference)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Semiconductor Science and Technology

Semiconductor Manufacturing

IEEE Transactions on Semiconductor Manufacturing

Links

This unit links to the following related units:

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 5025: Semiconductor Integrated Electronics

Unit Code: D/618/1766

Level: 5

Credits: 15

Introduction

Almost every aspect of our lives is affected by semiconductor devices. These devices are produced in their millions and are often seemingly invisible to their users. Although each device may only use small amounts of electrical energy, collectively they use an enormous amount of power. This unit investigates the characteristics of semiconductor devices and how they are integrated in applications such as digital systems, control, instrumentation, optical and communication networks that are in common use.

The physical structure of semiconductor devices is crucial to the understanding of their behaviour and how these parameters may be changed to meet the demands of different applications. This will allow the student to understand why different choices are made to arrive at the correct and most efficient processes to meet the need of the customer.

On successful completion of this unit students will be able to address complex semiconductor manufacturing processes resulting in the production of reliable and efficient electronic power devices.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Review the characteristics of semiconductor devices and how their physical structure varies in manufacture to produce the separate elements for integration into a complex integrated circuit

LO2 Investigate how common analogue and digital integrated circuits can be developed using basic active and passive elements, to produce single chip solutions

LO3 Investigate how adaptations to the semiconductor physical layers allow these devices to be used in a wide range of applications

LO4 Evaluate how semiconductor technologies and processes can produce reliable and efficient electronic power devices.

Essential Content

LO1 **Review the characteristics of semiconductor devices and how their physical structure varies in manufacture to produce the separate elements for integration into a complex integrated circuit**

Structure and characteristics of semiconductors:

Forming Insulators and conductors in silicon

Forming semiconductor junctions, creating Positive Negative (PN) junctions and Positive Negative Positive (PNP) and Negative Positive Negative (NPN) devices. Bipolar junction transistor families and their characteristics and limitations

Creating integrated electronic circuits.

Metal-Oxide-Semiconductor Technology:

Metal-Oxide-Semiconductor (MOS) families; Positive Metal-Oxide-Semiconductor (PMOS), Negative Metal-Oxide-Semiconductor (NMOS) and Complementary Metal-Oxide-Semiconductor (CMOS) and their characteristics

Fabrication of MOS devices; Field effect devices (MOSFET)

Comparison of Bipolar and MOS devices.

LO2 **Investigate how common analogue and digital integrated circuits can be developed using basic active and passive elements (resistors, capacitors, diodes and transistors), to produce single chip solutions**

Analogue and digital integrated circuits:

Analogue integrated circuits (IC's), their characteristics, and limitations. Interconnecting different cells of an IC to the metal lead frame using metal- evaporation and sputtering

Digital integrated circuits, different characteristics and limitations. Logic devices and microprocessor devices

Integrating analogue and digital elements; System on chip solutions, Microcontroller Unit (MCU) and embedded systems.

LO3 **Discuss how adaptations to the semiconductor physical layers allow these devices to be used in a wide range of applications**

Modifications in processing technology to enhance chip performance for various applications:

Developments in manufacturing process introduced to meet technical demands of new products. Adapting the manufacturing process to increase system performance in areas of Radio frequency and high-speed (memory) processing applications. Effect of changing the following aspects of semiconductor fabrication; physical dimensions of internal connectors, size of die, etching, doping, diffusion, materials, and ionic implantation

Manufacturing processes to create semiconductor devices for the photo-electric and optical industries. Visible light emitting diodes (VLED) or light emitting diode (LED); Infrared light emitting diode (ILED); light sensitive devices; liquid crystal displays; Laser diodes and solar cells.

LO4 **Evaluate how Semiconductor Technologies and processes can produce reliable and efficient electronic power devices.**

Physical limitations of semiconductor materials:

Thermo-electric breakdown, conductivity modulation, electrical spatial current instability, physical dimensions, and packaging. Switching speed

Different levels of complexity; phenomenological, analytical and numerical simulation. Local structure defects, physical safe operating levels (Voltage, Current and Power). Catastrophic failures. Environmental effects on reliability of Integrated circuits (ICs). Reliability assurance, safe operating area and electrostatic discharges (ESD). Methods of mitigating potential failures in ICs caused by exceeding safe operating levels

Semiconductor power devices, e.g., Silicon Controlled Rectifiers (SCR), power Metal Oxide Semiconductor Field Effect Transistors (MOSFETS), Insulated Gate Bipolar Transistors (IGBT).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Review the characteristics of semiconductor devices and how their physical structure varies in manufacture to produce a complex integrated circuit		
P1 Explore the characteristics of semiconductor devices and how their physical structure varies in manufacture. **P2** Describe how an integrated circuit could be formed using MOS devices.	**M1** Compare the differences in characteristics between bipolar and MOS devices when used in an integrated circuit.	**D1** Review the techniques for manufacturing a CMOS device that enables simplification of integrated circuit design.
LO2 Investigate how basic active and passive elements can be used to produce single chip solutions		
P3 Describe how electronic circuits can be developed using active and passive semiconductor elements.	**M2** Explain how individual semiconductor cells forming an integrated circuit can be connected to the supporting lead frame.	**D2** Review the technical issues when combining analogue and digital systems as found on MCU devices.

Pass	Merit	Distinction
LO3 Discuss how adaptations to the semiconductor physical layers allow circuits to be used in a wide range of applications		
P4 Explore how adaptions to the semiconductor physical layers allows circuits to be used in a wide range of applications. **P5** Investigate how the physical structure of a silicon capacitor made from a PN junction effects bandwidth and high frequency operation.	**M3** Discuss the principles supporting the operational characteristics of a light emitting diode (LED) and an infra-red LED.	**D3** Critically analyse how semiconductor manufacturing processes have had to be changed to be able to produce integrated devices for the mobile phone industry.
LO4 Evaluate how semiconductor technologies and processes can produce reliable and efficient electronic power devices.		
P6 Explore how semiconductor technologies and processes can produce reliable and efficient electronic power devices. **P7** Explain the problems caused by increasing the switching speed of a programmable logic device. **P8** Discuss typical safe operating and environment conditions when manufacturing an integrated circuit.	**M4** Assess how semiconductor devices may be protected from electrostatic discharges.	**D4** Critically evaluate the manufacturing techniques necessary to improve the reliability of an integrated circuit.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson R. L., and Anderson L. (2018) *Fundamentals of Semiconductor Devices.* 2nd Ed. Mc Graw Hill.

Dugaev V. and Litvinov V. (2021) *Modern Semiconductor Physics and Device Applications.* CRC Press.

Geng H. (2017) *Semiconductor Manufacturing Handbook*, Second Edition. McGraw Hill Professional.

Hughes E., Hiley J., Brown K. and McKenzie-Smith I. (2012) *Electrical and Electronic Technology*. Pearson.

May G. and Spanos C. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. John Wiley & Sons, Inc.

Nirmal D., Ajayan J. and Patrick J. F. (2021) *Semiconductor Devices and Technologies for Future Ultra Low Power Electronics*. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Semiconductor Science and Technology

Emerging Technologies in Wide-Bandgap Semiconductor Devices

Links

This unit links to the following related units:

Unit 4020: Digital Principles

Unit 4022: Electronic Circuits and Devices

Unit 5019: Further Electrical, Electronic and Digital Principles.

Unit 5026: Aircraft Flight Control Systems

Unit Code: T/651/0888

Level: 5

Credits: 15

Introduction

The need to control aircraft during all phases of flight has become ever more sophisticated as the complexity, size and flight speed of aircraft have increased. This has led to developments that increase the functionality, power output, fault tolerance and integration of the systems that provide flight control. With each aircraft generation, flight control system design has developed from simple manual and power-assisted mechanical systems, through to hydraulically and/or electrically powered and on to the advanced computer-controlled fly-by-wire and automatic flight control systems that we see today.

This unit will cover the design, development, and operation of flight control systems for fixed wing aircraft through the generations and introduces students to the design, development and operation of mechanical, hydraulic power and fly-by-wire systems, and automatic flight control in the form of autopilot and autoland systems.

On successful completion of this unit students will be able to determine the construction, layout and operation of mechanical flight control systems and control surfaces, examine the design and operation of fly-by-wire flight control systems, determine the functions and operation of autopilot and autoland flight control systems, and determine the contribution made to safe flight control by each system.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine how the construction, layout and operation of mechanical flight control systems contribute to safe flight control

LO2 Investigate how the design and operation of hydraulic powered flight control systems contribute to safe flight control

LO3 Investigate how the development and operation of fly-by-wire flight control systems contribute to safe flight control

LO4 Show how the functions and operation of autopilot and autoland flight control systems contribute to safe flight control.

Essential Content

LO1 **Determine how the construction, layout and operation of mechanical flight control systems contribute to safe flight control**

Flight control:

Control requirements; control about aircraft axes, roll, yaw, and pitch control, six degrees of freedom, control loads, artificial feel and trim

Flight control surfaces, construction, and aerodynamic operation: primary control surfaces, aileron, elevator, rudder; servo-tab, balance tab, trim tab; secondary control surfaces and devices, flap, slat, slot, flaperon, elevon, spoiler, vee-tail ruddervator.

Mechanical flight control systems and their components:

Construction, function, and layout of mechanical control system components: control column, wheels and levers, chains and sprockets, push/pull rods, bell crank levers, torque tubes, spring feel units, control cables, pulleys, cable tensioner, turnbuckles, fairleads

Pilot input and system response, push/pull control rod and cable and pulley systems.

Overview of control theory and architecture:

Control laws, analytical contexts of flight control, relevant case studies.

LO2 **Investigate how the design and operation of hydraulic powered flight control systems contribute to safe flight control**

Hydraulically powered flight control system component design and operation:

System requirements: sufficient power for control actuation, control surface rigidity, need for trim actuation, artificial (Q) feel, stall warning, redundancy provision

Constructional design, function, and operation of system major components: (Q) feel unit, trim actuator, hydraulic stick shaker; servo operated powered flying control unit (PFCU), hydro-mechanical power assisted and fully power operated PFCU, mechanically signalled hydraulic motor driven screw jack, electro-hydraulic PFCU.

Design architecture and operation of hydraulically powered flight control systems:

Hydro-mechanical and electro-hydraulic powered flying control systems: pilot inputs and system response; PFCU servo actions, inputs, outputs, closed loop feedback; system redundancy provision for primary and secondary control surface operation.

LO3 **Investigate how the development and operation of fly-by-wire flight control systems contribute to safe flight control**

Fly-by-wire (FBW) control system development:

Introduction of electronically controlled, hydraulically and electrically powered actuators

Solid state electronics for actuator control, pre-programmed computers and software interfacing for the control and integration of primary and secondary flight controls functions

Benefits resulting from FBW control: improved flight handling, reduction in airframe weight and control size, integration of flight control functions, flight envelope protection and alerting

Present and future benefits of fly-by-light (FBL) system signalling and control: further weight reduction from use of fibre-optic cabling and reduced component size, improved redundancy provision through system multiplexing.

Operation of FBW systems and components:

FBW powered flight control unit (PFCU) operation: electro-hydraulic and electro-mechanical actuators, pilot side stick and conventional controls inputs, hydraulic servo operation, hydraulic and electrical feedback, redundancy provision, design and operational considerations for risk mitigation and fault tolerance

FBW system control and operation: operating modes, pilot and autopilot signal conditioning, closed-loop control, transducers, and feedback circuitry; computer function, architecture, inputs, and outputs for FBW controls integration.

LO4 **Show how the functions and operation of autopilot and autoland flight control systems contribute to safe flight control**

Autopilot functions and operation:

Autopilot functions: maintenance of desired flight path and flight direction, pitch roll and yaw control

Autopilot servo-system operation: principles; error sensing inputs, correction, feedback and commanded outputs; circuitry signalling and actuation; input signals via transducers, error signal detection using electrical amplifiers, control surface actuation via servo-motor, position feedback signals to error detector amplifier

Autopilot operation for pitch, roll and yaw control; pitch damping and altitude hold, vertical speed, and level change commands; roll heading and navigation modes; yaw damper signalling, rudder servo motor action.

Automatic landing system functions and operation:

Instrument landing systems (ILS): function of aircraft and airfield navigation aids, automatic direction finder (ADF), distance measuring equipment (DMS), VHF omnidirectional range (VOR), during final approach, localiser and glideslope modes

Fully automatic landing system enhanced functionality and operation: functionality; radio altimeter, auto-throttle, enhanced ILS beam control laws, crosswind correction, continuation of runway flight guidance, go-round facility, continuous instrument display and monitoring; operation, during the approach, glideslope, and landing phases of flight.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine how the construction, layout and operation of mechanical flight control systems contribute to safe flight control		
P1 Discuss the control of fixed wing aircraft about their axes of rotation. **P2** Determine the function, layout and operation of mechanical flight control systems and components.	**M1** Explore the function, layout and operation of mechanical flight control systems and components, identifying the contribution made by the system to safe flight control.	**D1** Analyse the function, layout and operation of mechanical flight control systems and components, assessing the contribution made by the system to safe flight control.
LO2 Investigate how the design and operation of hydraulic powered flight control systems contribute to safe flight control		
P3 Investigate the design and operation of hydraulically power flight control system components. **P4** Illustrate the design and operation of hydro-mechanical and electro-hydraulic powered flight control systems.	**M2** Examine the design and operation of hydro-mechanical and hydro-electric powered flight control systems and their components, identifying the contribution made by each system to safe flight control.	**D2** Analyse the function, layout and operation of hydro-mechanical and hydro-electric powered flight control systems and their components, assessing the contribution made by each system to safe flight control.

Pass	Merit	Distinction
LO3 Investigate how the development and operation of fly-by-wire flight control systems contribute to safe flight control		
P5 Investigate the development and benefits of fly-by-wire control systems and components. **P6** Illustrate the operation of fly-by-wire control systems and components.	**M3** Justify the development and operation of fly-by-wire control systems and components, identifying the contribution made by these systems to safe flight control.	**D3** Examine how the development and operation of fly-by-wire control systems and components has contributed to safe flight control.
LO4 Show how the functions and operation of autopilot and autoland flight control systems contribute to safe flight control		
P7 Illustrate the functions and operation of a modern autopilot system and components. **P8** Show the functions and operation of modern instrument and fully automated landing systems and components.	**M4** Explore the functions and operation of modern autopilot, instrument and fully automated landing systems and components, by identifying the enhanced functions that contribute to safe flight and landing control.	**D4** Evaluate the functions and operation of modern autopilot, instrument and fully automated landing systems and components, assessing the enhanced functions that contribute to safe flight and landing control.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Barnhart K., Marshall D.M and Shappee E. (2021) *Introduction to Unmanned Aircraft Systems.* 3rd Ed. CRC Press.

Jackson S. (2020) *Systems Engineering for Commercial Aircraft − A Domain-Specific Adaptation.* 2nd Ed. Routledge.

Moir I. and Seabridge A. (2008) *Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration (Aerospace Series)*. 3rd Ed. Chichester: Wiley.

Wyatt D. (2015) *Aircraft Flight Instruments and Guidance Systems.* 1st Ed. Routledge.

Yu X., Guo L., Zhang Y. and Jiang J. (2022) *Autonomous Safety Control of Flight Vehicles.* 1st Ed. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Aerospace Magazine

Aerospace Science and Technology

Aerospace Systems

Control Engineering Practice

International Journal of Aerospace Engineering

Journal of Aerospace Engineering

SAE International Journal of Aerospace

The Aerospace Journal

Links

This unit links to the following related units:

Unit 4041: Aircraft Aerodynamics

Unit 5030: Aircraft Gas Turbine Engine Design and Performance.

Unit 5027: Aircraft Propulsion Principles and Technology

Unit Code: **Y/651/0889**

Level: **5**

Credits: **15**

Introduction

No matter what method of propulsion is used to propel aircraft through the air, they all rely on the principle laid down in Newton's third law, which states in its simplest form that to every action there is an equal and opposite reaction. The action force which we know as thrust may be provided by aircraft propellers or by the fluid stream from a jet engine exhaust, or by a combination of both.

This unit introduces students to the thermodynamic and mechanical principles that underpin aircraft propulsion and to gas turbine engine and piston engine construction, function and operation, as well as to the layout and operation of their associated components and support systems.

On successful completion of this unit students will be able to determine how thermodynamic and mechanical properties are applied to aircraft propulsion, and examine the construction, function and operation of gas turbine engines, their fluid, control and monitoring systems and piston engines and systems.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine how thermodynamic and mechanical principles are applied to aircraft propulsion

LO2 Examine the construction, function and operation of gas turbine engines and components

LO3 Examine the layout, function and operation of the fluid control and monitoring systems of gas turbine engines

LO4 Describe the construction, function and operation of piston engines and systems.

Essential Content

LO1 Determine how thermodynamic and mechanical principles are applied to aircraft propulsion

Thermodynamic principles applied to combustion engines:

The gas laws and the expansion and compression of perfect gases, constant volume, constant pressure, isothermal, adiabatic and polytropic processes

First law of thermodynamics applied to closed and open systems, non-flow (NFEE) and steady flow (SFEE) energy equations, concept of enthalpy in open systems, second law of thermodynamics applied to heat engines, measure of thermal efficiency

Thermal cycles and the concept of entropy, use of pressure-volume and temperature-entropy diagrams, the Otto cycle for spark ignition piston engines, the Joule constant pressure cycle for gas turbine engines

The practical four-stroke cycle for piston engines, performance indicators, indicated and brake power, engine thermal efficiency

The practical closed and open gas turbine cycle, losses compared with the ideal Joule cycle; thermal and propulsive efficiencies and measure of specific fuel consumption in aircraft gas turbine engines.

Mechanical principles applied to fluid flow and propulsive thrust:

Newton's laws of motion applied to fluid flow; momentum and kinetic energy of fluid flow, use of continuity, Bernoulli equation and SFEE for incompressible gas flows; compressible sonic flows, Mach number and airflow velocities, static and stagnation conditions, jet nozzle flow, chocked nozzles

Newton's laws and aircraft thrust from gas stream; gross thrust, intake drag force, net thrust, net thrust with pressure thrust, thrust power; propeller aerodynamics and thrust production

Appropriate calculations to support principles detailed above.

LO2 **Examine the construction, function and operation of gas turbine engines and components**

Types, construction and operation of gas turbine engines:

Turbojet engine: construction, arrangement and location of engine components and associated gearing and connections; operation, changes to the working fluid and the production of thrust as air/gas flows into the intake and through the compressor, combustor, turbine, propelling nozzle and exhaust components of the engine; operational limitations of the pure jet engine, noise pollution, reduced propulsive efficiency

Turbofan engine: construction, arrangement and operational differences between multi-shaft high bypass turbofan engines and the single shaft turbojet; relative advantages of turbofan engines over turbojets, fuel and propulsive efficiency, cooling and noise reduction

Turboprop engine: construction, arrangement and component location, addition of low-pressure turbine, main gearbox and propeller; operational differences in the production of thrust via a propeller; relative advantages/disadvantages over turbofan engines

Turboshaft engine: construction, arrangement and component location, introduction of larger diameter drive shaft and more robust compressors and turbines; operation for the production of torque to drive helicopter rotors; relative advantages in the use of this type of engine.

Function and operation of gas turbine engine components:

Function and operation of compressors: axial flow compressors, stage rotors and stators, working fluid temperature and pressure rises and governing factors, inlet guide vanes, variable stator vanes; centrifugal compressors, inlet duct and vanes, the impeller, rotating guide vanes and radial diffuser vanes, airflow pressure rise and centrifugal action

Function and operation of fans: compression of bypass air, supercharged air feed into core, need for multi-stage fans and form of fan blade, disc, attachments and casing

Combustors: types, multiple combustion chamber, tubo-annular and annular; requirements, high combustion efficiency, reliable ignition, restart facility, low-pressure losses and emissions, high durability; function and operation, control of combustible gases, fuel injectors, vaporisers, spray nozzles, ignitors and combustion chamber cooling

Function and operation of turbines: single and multi-stage, impulse and reaction turbines, energy transfer from the working fluid, turbine casing, discs, shafts and nozzle guide vanes, turbine cooling and constructional materials limitations

Function and operation of intakes and exhausts: intakes, bell-mouth, circular, variable geometry, drag minimisation at cruise speeds, integration with engine cowlings; exhausts, gas exhaust propelling nozzles, reverse thrusters, thrust vectoring nozzles, after burners

Appropriate calculations to support principles detailed above.

LO3 **Examine the layout, function and operation of the fluid control and monitoring systems of gas turbine engines**

Layout and operation of turbine engine fluid systems:

Engine fuel systems: airframe and engine fuel system interaction requirements, avoidance of fuel contamination and suction operation, priming, re-priming and relight facilities; component identification, function and layout; function and operation of typical engine fuel system including operation of hydro-mechanical fuel meeting unit

Engine lubrication systems: lubricant types, properties, identification and use of additives; oil system functions; function and layout of lubrication system components; operation of recirculatory lubrication systems, pressure relief and full flow systems and pressure feed and distribution, scavenge and vent sub-systems

Internal air systems: functions cooling, sealing and bearing load control; function and operation of air cooling system; identification, functions and nature of air system seals and sealing methods.

Function and operation of engine control and monitoring systems:

Engine electro mechanical control systems: function and operation of mechanical cables, rods and pilot control levers, electrically actuated valves and switches; function and operation of auto-throttle, regulation and switching, flight/ground idle control

Electronic engine control systems: identification and function of typical electronic control system components, electronic controller, demand and feedback sensors, fuel pumps and fuel metering controller; function and operation of FADEC system, electronic engine controller (EEC), fuel metering unit (FMU) and fuel control monitoring

Engine performance and condition monitoring systems: instrumentation and measurement of engine temperature, pressure ratio, rotational speed and thrust performance parameters; vibration and lubrication condition monitoring, use of magnetic chip detectors.

LO4 **Describe the construction, function and operation of piston engines and systems**

Piston engine construction, operation and installation:

Engine construction and operation: crankcase, crankshaft, cylinder and piston assemblies, valve mechanism and timing, accessory and propeller reduction gearboxes, two and four stroke cycle operation, power and efficiency parameters and their monitoring and measurement

Power plant installation: configuration and function of firewalls, cowlings, acoustic panels, engine mounts, anti-vibration mounts.

Function and operation of piston engine fluid, ignition and control systems:

Engine fuel and fuel metering systems: fuel system requirements, fuel metering devices; carburation principles, float and pressure injection carburettors, automatic mixture control; fuel-injection systems, fuel injectors and pumps, airflow/fuel regulation and metering; supercharged induction systems, turbochargers and their control

Lubrication systems: functions, types and characteristics of engine oil lubricants; lubrication system requirements; combined splash and pressure lubrication; dry and wet sump lubrication system components and operation

Engine ignition, control and starter systems: magneto-ignition principles, circuit operation and components; full authority electronic digital control (FADEC) system operation and function of electronic control unit (ECU) and associated software, redundancy requirements for safety, booster coil, impulse coupling and retard breaker vibrators; inertia starters, direct cranking electric starter system operation and monitoring.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine how thermodynamic and mechanical principles are applied to aircraft propulsion		
P1 Synthesise the use of thermodynamic principles applied to reciprocating piston engine and aircraft gas turbine engine operating cycles as part of reviewing a given work related scenario. **P2** Determine how the mechanical principles apply to the production of propulsive thrust by piston-propeller and gas turbine engine driven aircraft.	**M1** Explain, with the use of calculations, the thermodynamic and mechanical principles applied to the operating cycles and production of propulsive thrust by piston-propeller and gas turbine engine driven aircraft, identifying the relative merits of each method of propulsion.	**D1** Analyse the thermodynamic and mechanical principles applied to the operating cycles and production of propulsive thrust by piston-propeller and gas turbine engine driven aircraft, assessing the relative merits of each method of propulsion.
LO2 Examine the construction, function and operation of gas turbine engines and components		
P3 Illustrate the construction and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines. **P4** Examine the function and operation of gas turbine engine, intake, compressor, combustor, turbine and exhaust components.	**M2** Explore the construction, function and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines and their components, identifying, with calculations, the relative performance of each engine type.	**D2** Analyse the constructional features, function and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines and their components, assessing the relative performance of each engine and component arrangement.

Pass	Merit	Distinction
LO3 Examine the layout, function and operation of the fluid control and monitoring systems of gas turbine engines		
P5 Illustrate the layout and operation of engine fuel, lubrication and internal air fluid systems. **P6** Examine the function and operation of engine electro-mechanical, electronic and FADEC control systems and engine monitoring systems.	**M3** Explain the layout and operation of engine, fluid control and monitoring systems and the function and operation of the major components for each system.	**D3** Analyse the layout and operation of engine, fluid control and monitoring systems, including assessing the effect that the operation of their major components has on each system.
LO4 Describe the construction, function and operation of piston engines and systems		
P7 Describe the construction, operation and installation of aircraft reciprocating piston engines. **P8** Illustrate the function and operation of engine fuel, lubrication, ignition, control and starter systems.	**M4** Explore the construction and operation of aircraft reciprocating piston engines and their supporting systems, identifying the function and layout of the major components, for each supporting system.	**D4** Evaluate the constructional features and operation of aircraft reciprocating piston engines and their associated ancillaries and supporting systems, assessing the operational benefits for the choice and layout of the major components, for each supporting system.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Farokhi S. (2021) *Aircraft Propulsion: Cleaner, Leaner, and Greener*. 3rd Ed. Wiley.

Haran K., Madavan N. and O'connell T.C. (2022) *Electrified Aircraft Propulsion: Powering the Future of Air Transportation.* Cambridge University Press.

Royce R. (2015) *The Jet Engine.* 5th Ed. Chichester, West Sussex: John Wiley & Sons.

Saravanamuttoo H. I. H., Rogers G. F. C., Cohen H., Straznicky P. V. (2009) *Gas Turbine Theory*. 6th Ed. Pearson.

Tooley M., and Dingle L. (2012) *Engineering Science, Part III*. Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Aerospace

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

International Journal of Aerospace Engineering

Journal of Aircraft

Journal of Aerospace Engineering

Journal of Aerospace Information Systems

Journal of Propulsion and Power

SAE International Journal of Aerospace

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 5005: Further Thermodynamics

Unit 5028: Aircraft Structural Integrity

Unit Code: F/651/0890

Level: 5

Credits: 15

Introduction

To ensure the integrity of aircraft structures and structural components, the designer must consider the properties, failure characteristics and selection of aircraft materials used for the construction, repair, and maintenance of the airframe, in conjunction with the loading criteria, in-service role and operation of the aircraft. This unit introduces you to the materials science, failure analysis, repair techniques, design, policies, and procedures that collectively ensure the integrity and continued airworthiness of the aircraft's structure.

This unit introduces students to the properties and selection of materials used for the construction and repair of the airframe, the stress analysis methods and tools, the prediction of structural damage and design against failure, the methods and design of adhesively bonded repairs, as well as to the policies, procedures and regulation used to ensure the integrity of aircraft structures during service.

On successful completion of this unit students will be able to learn about the design criteria, properties, and selection of aircraft metallic and composite structural materials; stresses in structural components, examine aircraft structural fatigue, damage prediction and design against failure; fibre composite adhesively bonded repairs to aircraft metallic and composite structures; and how policies, procedures and regulations are used to ensure the integrity of aircraft structures.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate the design criteria, properties, and selection of metallic and composite aircraft structural materials

LO2 Analyse aircraft structural elements using structural analysis theories and industry-relevant software tools

LO3 Investigate aircraft structural fatigue, damage prediction and design against failure

LO4 Demonstrate how policies, procedures and regulations are used to ensure the integrity of aircraft structures.

Essential Content

LO1 **Evaluate the design criteria, properties, and selection of metallic and composite aircraft structural materials**

Design criteria for aircraft structural materials:

General: purchase, maintenance and repair costs, availability, ease of manufacture and fabrication

Industry 4.0 context: impact on design and selection of materials; integration aspects linking to automation, digital systems and manufacturing engineering systems; overall organisational impact

Environmental durability: corrosion, moisture absorption, wear, and erosion resistance

Mechanical properties: density (ρ), stiffness (elastic modulus E), strength (yield stress σ_y), shear strength (τ), structural efficiency measured by, specific stiffness (E/ρ) and specific strength (σ/ρ), fatigue resistance, fatigue stress (σ_{fs}) fracture toughness (K_c), impact resistance, strength, and stiffness parameter calculations

Thermal and electrical properties: high temperature resistance, creep resistance, electrical conductivity, radar transparency

Documentation control within the context: processes and procedures such as format, location, access, authorisation.

Common aircraft structural materials and their properties:

Metallic-alloys: Aluminium lithium (8090), copper (2014, 2024) and magnesium (7075) alloys; high temperature titanium alloys (e.g., Ti-6Al-4V); high strength steels, nickel-based super alloys

Composites: Polymer matrix composites (PMC) (e.g., epoxy, PEEK), metal matrix composites (MMC), fibre-metal laminates (FML), ceramic matrix composites (CMCs), glass reinforced aluminium (GLARE) property parameters including: tensile, compressive and shear strength, elastic and shear modulus, specific strength and stiffness, hardness, fracture toughness, crack growth resistance and corrosion resistance for metallic alloy and composite materials

Use cases for materials, for example light and wide-body aircrafts.

Materials selection:

Using design criteria select appropriate metallic and composite materials for: wing, fuselage and empennage skins, leading edges, fuselage frames and stringers, undercarriage struts, engine turbines, jet pipes and exhausts, for both modern military fighter and commercial aircraft and make comparisons between the choice of materials

Within the context: applications and benefits of tools and techniques associated with lean manufacturing and process improvement such as seven wastes, continuous flow, Kanban (pull System), just-in-time (JIT), lean simulation activities, value stream mapping, Poke Yoke.

Within the context: application and benefits of different production methods e.g. single, batch, flow, mass.

LO2 Analyse aircraft structural elements using structural analysis theories and industry-relevant software tools

Basic structural elements of aircraft structures:

Axial member, bending beam, shear panel, torsion member; wing and fuselage structural construction and load transfer.

Bending and shear of open and closed thin-walled beams:

Euler-Bernoulli beam theory, unidirectional and bidirectional bending of beams with symmetric and asymmetric cross-sections, transverse shear stress in beams; shear flow and shear center in thin-walled open and closed beam sections.

Torsion of thin-walled beams:

Torsion of bars with circular cross-section, shear flow and twist of single-cell and multi-cell thin-walled sections.

Analysis case studies:

Structural analysis of idealised aircraft structural components using industry-relevant finite element analysis tools (e.g. Ansys, Nastran, Abaqus), conduct analysis for stress distributions under different load cases, such as bending, torsion, compression (including buckling) and combined loads.

LO3 Investigate aircraft structural fatigue, damage prediction and design against failure

Nature of fatigue:

Sources: alternating, fluctuating, and repeating cyclic stressing, corrosion, fretting, thermal and acoustic

Fatigue parameters: representation on S-N curves, fatigue strength, fatigue limit, endurance limit, fatigue behaviour in ferrous and non-ferrous light alloy and composite structures.

Fatigue damage prediction:

Fatigue life prediction methods: structural fatigue testing; use of empirical stress relationships, Goodman equation, Gerber parabolic equation, Soderberg equation, Miner's law of cumulative damage; use of ground-air-ground and gust load cycles and fatigue meters

Use of linear elastic fracture mechanics (LEFM): fracture mechanisms, slip, plastic deformation, and dislocations, ductile transgranular fracture, brittle fracture (cleavage); the Griffith energy balance and Irwin's stress intensity approach to predict fatigue crack behaviour including, stress concentration and intensity factors, crack tip plasticity, fracture toughness, critical crack growth, propagation rates and time to failure predictions

Creep failure prediction; characteristics, stages creep rate and rupture times, kinetic heating effects.

Aircraft structure design prevention methods:

Correct materials selection based on design criteria

Use of jointing compounds, surface hardening and finish, doublers, and butt straps

Avoidance of sudden changes in cross-section and bend designs that trap moisture and dirt

Use of aircraft structural failure categorisation methods: primary, secondary, and tertiary structures; structurally significant items (SSIs); fail safe, damage tolerant and safe life design

Analysing and interpreting data/information within the context for documentation such as Parts Per Million (PPM) quality adherence, cost analysis and test data.

LO4 **Demonstrate how policies, procedures and regulations are used to ensure the integrity of aircraft structures**

Damage assessment methods:

General damage assessment including; visual inspection of metallic and composite structure for corrosion and impact damage, surface damage, cracking, water ingress aided by moisture meter and delamination aided by 'tap test'

Non-destructive evaluation (NDE) of structural damage using e.g., optical, penetrant dye, ultrasonic, radiographic, eddy current and thermography techniques.

Repair policies and procedures:

Repair policies: repair and maintenance organisation considerations; damage assessment methods, repair categorisation, downtime, costs, repair by replacement, physical and human resource requirements; structural integrity policies for e.g., aging aircraft, fighter aircraft

Procedures: governance, compliance and quality management systems e.g. ISO 9001, AS 9100, ISO 14001, TS 16949; quality assurance procedures for repair integrity and airworthiness; procedures and manuals for the damage assessment and repair of metallic and polymer-matrix composite structures and structural components

Field repair considerations e.g., simple techniques, limited use of repair equipment, first-aid and temporary repair techniques, availability of cure facilities.

Aircraft structural integrity care and maintenance programmes and regulations:

Inspection: nature and frequency of inspection, structural component access and component life considerations

Design of aircraft structural integrity care and maintenance programmes, policies, and procedures

Hard time and on-condition monitored maintenance planning and its relationship to aircraft structure

Information sources and repair and maintenance actions: statistical information sources and corresponding reliability techniques; data collection and structural component history; maintenance reporting procedures; corrective action methodology and quality assurance procedures

Regulations e.g., European Aviation Safety Agency (EASA), Civil Aviation Authority (CAA), Ministry of Defence (MOD) and/or Aircraft Manufacturers regulations for the integrity and continuing airworthiness of aircraft structures, structural components, and ageing airframes; compliance with the organisation's approved standard operating procedures (SOPs), documentation recording systems, and risk assessment, and implications for safety, quality and delivery if they are not adhered to.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the design criteria, properties, and selection of metallic and composite aircraft structural materials		**D1** Develop a case for the selection of common metallic and composite structural components in a given situation, assessing the choices made between different candidate materials.
P1 Discuss the design criteria and common metallic and composite material properties required for aircraft structural materials. **P2** Evaluate appropriate metallic and composite materials by comparison for aircraft structural components, using design criteria for light and wide-body aircraft.	**M1** Explore the material properties and design criteria needed for the selection of common metallic and composite aircraft structural components, making choices between the selection of different candidate materials.	
LO2 Analyse aircraft structural elements using structural analysis theories and industry-relevant software tools		**D2** Develop finite element models of idealised aircraft structural components, using commercial software tools, to analyse stress and displacement distributions subjected to bending, shear or torsional loads.
P3 Analyse stresses due to bending of beams with symmetric and unsymmetrical cross-sections. **P4** Determine shear centre and shear flow due to bending of thin-walled open beam cross-sections.	**M2** Investigate shear flow in single-cell and multi-cell closed tubes subjected to shear and torsional loads.	

Pass	Merit	Distinction
LO3 Investigate aircraft structural fatigue, damage prediction and design against failure		
P5 Investigate the nature of fatigue and the quantitative methods used to predict fatigue behaviour in aircraft structures. **P6** Illustrate the design prevention methods used to mitigate the effects of aircraft structural damage from fatigue.	**M3** Investigate fatigue, the quantitative prediction of fatigue behaviour and the design methods used to mitigate its damaging effects to aircraft structure and structural components.	**D3** Evaluate a given material selection decision, showing how fatigue, the quantitative prediction of fatigue behaviour and the design methods used to mitigate its damaging effects to aircraft structure and structural components are used to justify the use of a particular material.
LO4 Demonstrate how policies, procedures and regulations are used to ensure the integrity of aircraft structures		
P7 Demonstrate how damage assessment methods, policies and procedures are used to ensure that aircraft structures are correctly repaired. **P8** Illustrate how care and maintenance programmes, procedures and authority regulations ensure the integrity and airworthiness of aircraft structures.	**M4** Investigate how damage assessment methods, repair and maintenance policies, procedures and authority regulations ensure the correct repair, integrity and airworthiness of aircraft structures.	**D4** Construct a damage assessment report that shows how damage assessment methods, repair and maintenance policies, procedures and regulations are used to ensure the correct repair is selected to ensure integrity and airworthiness of aircraft structures.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Ashb, M. F. (2010) *Materials Selection in Mechanical Design*. 4th Ed. Elsevier.

Baker A., Dutton S., and Kelly D., (2004) *Composite Materials for Aircraft Structures.* 2nd Ed. American Institute of Aeronautics and Astronautics (AIAA).

Higgins R.A. (2010) *Materials for Engineers and Technicians.* London: Edward Arnold.

Megson T. M. G. (2012) *Aircraft Structures for Engineering Students,* Butterworth-Heinemann. 5th Ed.

Mouritz A.P. (2012) *Introduction to aerospace materials.* Cambridge: American Institute of Aeronautics and Astronautics.

Sun C. T., and Adnan A. (2021). *Mechanics of aircraft structures.* John Wiley & Sons, 3rd Ed.

Janssen M., Zuidema J. and Wanhill, R., (2009) *Fracture Mechanics*. Spoon Press, imprint of Taylor & Francis.

Megson T.H.G. (2017) *Introduction to Aircraft Structural Analysis* (Paperback). Elsevier Science & Technology.

Mouritz P. A. (2012) *Introduction to Aerospace Materials.* Woodhead Publishing.

Wanhill R., Barter S. and Molent L. (2019) *Fatigue Crack Growth Failure and Lifing Analyses for Metallic Aircraft Structures and Components − SpringerBriefs in Applied Sciences and Technology* (Paperback). Springer.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

AIAA Journal from the American Institute of Aeronautics and Astronautics

International Journal of Aerospace Engineering

International Journal of Structural Integrity

Journal of Aerospace Engineering: Mechanical Engineers Part G.

Journal of Materials Design and Applications: Mechanical Engineers Part L.

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4009: Materials, Properties and Testing

Unit 4044: Composite Materials for Aerospace Applications

Unit 5031: Advanced Composite Materials for Aerospace Applications.

Unit 5029: Avionic Systems

Unit Code: H/651/0891

Level: 5

Credits: 15

Introduction

The term 'avionics' refers to the vast range of electronic systems used on any modern aircraft. These systems include those used for radio communication, navigation, weather radar, autopilot, and instrument landing systems (ILS), as well as a host of other systems essential to supporting an aircraft whilst in flight and on the ground. All of these systems reduce the burden on the flight crew and significantly improve the safety and stability of the aircraft.

This unit will provide the student with a comprehensive introduction to the avionic systems used on modern aircraft. They will investigate several of these systems in detail and will gain an understanding of the technologies on which each of these systems is based as well as their practical application. The way these systems work together to minimise the workload on the flight crew and contribute to safe and fuel-efficient flight will also be covered.

The unit is divided into four key topic areas: aircraft radio communication systems, aircraft navigation systems, aircraft radar, and automatic flight control systems (AFCS).

On successful completion of this unit students will be able to interpret avionic system schematic diagrams, identify the practical application of components and sub-systems, and understand the principles on which they operate.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Demonstrate conceptual understanding of the principles and practical application of HF, VHF and UHF aircraft radio communication systems

LO2 Investigate the principles and practical application of aircraft navigation systems

LO3 Develop investigative knowledge of the principles and practical applications of aircraft radar and ADS-B systems

LO4 Demonstrate the principles and practical application of automatic flight control systems (AFCS).

Essential Content

LO1 **Demonstrate conceptual understanding of the principles and practical application of HF, VHF and UHF aircraft radio communication systems**

Principles of aircraft radio communication:

Electromagnetic waves

The electromagnetic wave spectrum

Frequency, wavelength, and velocity of propagation

Wave propagation in free-space, waveguides, and cables

Characteristic impedance

Radio propagation at HF, VHF and UHF

Antennas for HF, VHF and UHF radio communication

Isotropic radiators. Antenna gain and directivity

Feeders and cables for RF

Voltage standing wave ratio (VSWR).

Radio transmitter principles:

Oscillators

Phase-locked loops (PLL)

Digital frequency synthesis

Modulation: DSB AM, SSB, FM, PSK

Power amplifiers

Class of operation

Harmonic suppression

Antenna coupling

Standing wave ratio.

Radio receiver principles:

Sensitivity and selectivity

The super-heterodyne principle

Mixers and IF amplifiers

Image and adjacent channel rejection

RF and IF filters

Demodulators (DSB AM and SSB)

Automatic gain control (AGC)

Automatic frequency control (AFC)

Digital signal processing (DSP) techniques

Software-defined radio (SDR) receivers

HF aircraft radio communication:

HF spectrum allocation, channels and channel spacing

Typical aircraft HF radio systems

HF radio antennas

Antenna coupling and loading

HF SSB voice communication

HF data-link (HFDL).

VHF aircraft radio communication:

VHF spectrum allocation, channels and channel spacing

Typical aircraft VHF radio systems

VHF radio antennas

VHF AM voice communication

VHF data-link (VHFDL).

Satellite Communication (SATCOM):

Use of SATCOM in Air Traffic Management

Current trends and future scope.

Safety and certification requirements of aircraft communication systems.

LO2 **Investigate the principles and practical application of aircraft navigation systems**

Principles of air navigation:

Aircraft synchro and servo systems

Terrestrial magnetism and magnetic compass systems

Gyroscopic and inertial navigation principles

VHF Omni-directional Ranging (VOR) principles

Distance Measuring Equipment (DME) underpinning theory

Instrument Landing System (ILS) underpinning theory

Principles of air data systems

Principles of inertial navigation systems (INS)

Tactical Air Navigation (TACAN) – Military Aircraft Systems.

Area navigation:

Principles of area navigation (RNAV)

Contributory systems (VOR and DME)

Line of sight range (LOS)

RNAV equipment, control and display units (CDU)

RNAV geometry

Navigational databases

Required navigation performance (RNP)

Flight management systems (FMS):

Principles of FMS

Lateral and vertical navigations
Advantages of FMS

Flight management computer systems (FMCS)

FMCS control and display units (CDU)

CDU information pages and displays

System initialisation.

Global navigation satellite systems (GNSS):

Global positioning system (GPS)

GPS principles

GPS segments (space, control and user)

GPS signals and codes

GPS accuracy and errors.

Safety and certification requirements of aircraft navigation systems.

LO3 **Develop investigative knowledge of the principles and practical applications of aircraft radar and ADS-B systems**

Radar principles:

Primary and secondary radar systems

The radar range equation

Pulsed and continuous wave (CW) radar systems

Duty cycle, peak and average power.

Weather radar systems:

Weather radar principles

Radar antennae (parabolic and flat plate)
Radar transmitters, receivers and displays

Electronic flight instrument displays (EFIS)

Cloud formation and the detection of precipitation.

Surveillance radar systems:

Surveillance radar principles

Primary surveillance radar (PSR) and secondary surveillance radar (SSR)

Radar transponders

Air traffic control (ATC) radar (modes A, C and S)

Traffic alert and collision avoidance systems (TCAS).

ADS-B systems:

Automatic dependent surveillance-broadcast (ADS-B) principles

ADS-B transmitting and receiving equipment.

LO4 **Demonstrate the principles and practical application of automatic flight control systems (AFCS)**

Autopilot and flight director principles:

Servo principles

Feedback systems

Demand, command, and feedback signals

Gyro principles

Vertical gyro

Autopilot modes

Three-axis control

Pitch control

Roll control

Yaw damping

Software and flight control laws for autopilot systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Demonstrate conceptual understanding of the principles and practical application of HF, VHF and UHF aircraft radio communication systems		
P1 Illustrate the relationship between frequency, wavelength, and velocity of propagation of an electromagnetic wave. **P2** Explore the functional elements of AM radio receivers and transmitters. **P3** Interpret key performance specifications of an aircraft voice communication system. **P4** Demonstrate a typical radio data-link system (HFDL or VHFDL) for use in an aircraft.	**M1** Explore the main features and characteristics of radio wave propagation at HF, VHF and UHF. **M2** Discuss full-carrier amplitude and suppressed carrier single-sideband modulation techniques (DSB AM and SSB). **M3** Discuss a typical VHF antenna for use on an aircraft and justify the need for a matched antenna system in terms of radiated power and voltage standing wave ratio.	**D1** Critically evaluate the performance of a typical HF SSB or VHF AM transceiver in terms of receiver sensitivity, selectivity, output power and modulation depth for AM or peak-envelope-power (PEP) for SSB, frequency accuracy and stability.
LO2 Investigate the principles and practical application of aircraft navigation systems		
P5 Explain the typical arrangement of remote indicating compass for use on a typical modern civil aircraft. **P6** Investigate the range of navigational aids and techniques available for use in a typical modern civil aircraft.	**M4** Discuss the underpinning principles of VOR- and DME-based navigation aids. **M5** Review the principles of gyroscope-based inertial navigation and its limitations in providing accurate global aircraft navigation.	**D2** Critically assess the benefits of area-based navigation (RNAV) when compared with satellite-based navigation for a typical modern civil transport aircraft.

Pass	Merit	Distinction
LO3 Develop investigative knowledge of the principles and practical applications of aircraft radar and ADS-B systems		**D3** Critically evaluate the performance of an SDR-based ADS-B receiver and the data obtained during the typical flight of a modern commercial transport aircraft.
P7 Differentiate between primary and secondary radar systems and describe an example of each. **P8** Investigate the use of radar in air traffic control (ATC) applications. **P9** Illustrate the functional components of an aircraft weather radar system. **P10** Develop comprehensive knowledge of the benefits of ADS-B as a means of providing real-time data.	**M6** Illustrate the relationship between peak power, mean power and duty cycle of a primary radar system **M7** Distinguish between the three basic ATC transponder modes (A, C and S)	
LO4 Demonstrate the principles and practical application of automatic flight control systems (AFCS)		**D4** Analyse performance of the flight director system of a modern civil transport or general aviation (GA) aircraft in terms of the individual autopilot system components and the contribution that they collectively make to the attitude, stability and course of the aircraft.
P11 Discuss the reasons for using closed loop feedback in automatic flight control systems. **P12** Demonstrate key autopilot control modes and their function in relation to an aircraft's attitude and stability.	**M8** Illustrate the principle of three-axis control of an aircraft's attitude. **M9** Illustrate the function of a yaw damper.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Agrawal B.N. and Platzer M.F. (2018) *Standard Handbook for Aerospace Engineers.* 2nd Ed. McGraw-Hill.

Collinson R.P.G. (2023) *Introduction to Avionics Systems.* 4th Ed. Springer.

Croucher P. (2015) *Avionics in Plain English*. Calgary, Alberta: Electrocution.

Lawrenson A., Rodrigues C.C., Malmquist S., Greaves M., Braithwaite G. and Cusick S.K. (2023) *Commercial Aviation Safety.* 7th Ed. McGraw-Hill.

Moir I., Seabridge A. and Jukes M. (2013) *Civil Avionics Systems*. Wiley-Blackwell.

Sasidharan A. (2019) *Flight Avionics Yearbook 18/19.* Jane's Information Group.

Spitzer C., Ferrell U. and Ferrell T. (Editors) (2017) *Digital Avionics Handbook Paperback*. CRC Press.

Tooley M. and Wyatt D. (2017) *Aircraft Communication and Navigation Systems*. 2nd Ed. Butterworth-Heinemann.

Wang G. and Zhao W. (2020) *The Principles of Integrated Technology in Avionics Systems.* 1st Ed. Academic Press.

Wyatt D. (2015) *Aircraft Flight Instruments and Guidance Systems.* Routledge.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advances in Avionics and Astrionics Systems

Aerospace – Avionic Systems

AIAA Journals

Aviation Week and Space Technology

Chinese Journal of Aeronautics (Avionics and Autocontrol)

Links

This unit links to the following related units:

Unit 4016: Instrumentation and Control Systems

Unit 4019: Electrical and Electronic Principles.

Unit 5030: Aircraft Gas Turbine Engine Design and Performance

Unit Code: **J/651/0892**

Level: **5**

Credits: **15**

Introduction

Gas turbine engines have become the major source of propulsive power for modern-day commercial and military aircraft, due to their superior power output and efficiency savings in relation to their reciprocating piston counterparts. The current imperatives are for engines to be designed that are quieter, cleaner, more efficient, have greater power and improved performance.

This unit introduces students to the thermo-fluid principles and propulsion cycles used to assess the overall efficiencies of gas turbine engines, and to the design and performance of the turbomachinery, intake, combustion and exhaust modules that provide the propulsive thrust, as well as to the relationship between their design, performance and effect on the environment.

On successful completion of this unit students will be able to develop broader and deeper knowledge and skills on gas turbine engine performance using thermo-fluid principles and propulsion cycle efficiencies; the design and performance of aircraft gas turbine engine turbomachinery, intake, combustion and exhaust modules; and the factors affecting the design, performance of gas turbine powered aircraft operation and associated environmental impact.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine gas turbine engine performance, using thermo-fluid principles and propulsion cycle efficiencies

LO2 Evaluate the design and performance of aircraft gas turbine engine turbomachinery

LO3 Develop an evaluation of the design and performance of aircraft gas turbine engine intake, combustion and exhaust modules

LO4 Investigate the factors affecting the design, performance and environmental impact of gas turbine powered aircraft operation.

Essential Content

LO1 **Determine gas turbine engine performance, using thermo-fluid principles and propulsion cycle efficiencies**

Thermo-fluid principles applied to propulsion cycles:

Gas laws and the characteristic gas equation ($pv = mRT$), specific heat capacities for fluids

Perfect gas processes; constant volume, constant pressure, isothermal, adiabatic, reversible adiabatic (isentropic), polytropic; ratio of specific heats and the adiabatic index ($c_p/c_v = \gamma$)

Concept of entropy, entropy change and specific entropy change in non-isentropic processes, representation of entropy change on T – s diagrams

Constant pressure/Joule cycle: isentropic compression, reversible constant pressure heat supply, isentropic expansion, reversible constant pressure heat rejection; representation on p – V and T – s diagrams; air standard efficiency and work ratio

Newton's laws and propulsive thrust; gross thrust, intake drag force, net thrust, net thrust with pressure thrust, thrust power

Fluid flow in open systems, potential, kinetic and heat energy of the working fluid, steady flow energy equation (SFEE) and the concept of enthalpy and specific enthalpy

Compressible fluid flows: through ducts and nozzles, static (*p, T, h*, pressure, temperature, specific enthalpy) and stagnation (p_0, T_0 , h_0) properties; ram pressure rise, ram pressure ratio; sonic velocity

$a = \sqrt{(\gamma RT)}$; flow through shockwaves, representation of normal shock on T – s diagram

Isentropic flow relationships; T_0/T and p_0/p in terms of the adiabatic index (γ) and Mach number (M) and mass flow parameters in terms of continuity equation and the characteristic gas equation where mass flow.

$$(m) = \frac{pAM\sqrt{(\gamma RT)}}{RT}.$$

Gas turbine propulsion cycles and engine performance prediction:

The *ideal* turbojet cycle: station numbering; intake airflow adiabatic and without friction, isentropic compression in flight; isentropic compression through compressor; constant pressure heat addition in the combustor; isentropic expansion through turbine; frictionless adiabatic flow through jetpipe; isentropic expansion through exit nozzle; cycle representation on T – s diagram

Component losses: aerodynamic through ducts and over bodies, thermodynamic heat losses and incomplete energy release from fuels; thermodynamic imperfections, compression and expansion processes depart from the ideal

Component isentropic efficiencies to account for losses, through intake, compressor, combustor, turbine, jetpipe and final nozzle

Turbojet cycle calculations using realistic component isentropic efficiencies

Turboprop cycle: differences from pure turbojet; stage numbering, power turbine, driveshaft, reduction gearbox and propeller; representation on T – s diagram; cycle calculations

High bypass turbofan cycle: differences from turbojet and turboprop; stage numbering proportion of bypass flow, bypass ratio, hot and cold exit nozzles; representation on T – s diagram; cycle calculations

Measures of performance: propulsive efficiency $\eta_p = 2/1+(V_j/V_a)$, thermal efficiency

$\eta_t = 0.5m(V_j{}^2 - V_a{}^2)/fC$ and overall efficiency $\eta_t = m(V_j - V_a)V_a/fC$ (f = fuel flow rate, C = calorific value of fuel, m = mass flow rate)

Performance comparisons between turbojet, turboprop and turbofan.

LO2 **Evaluate the design and performance of aircraft gas turbine engine turbomachinery**

Axial flow compressors:

Function and advantages over centrifugal type

Multi-stage configuration, disc, stator and rotor action, pressure and temperature rise, pressure ratio

Stage aerodynamics and operation: flow of air through a stage, use of velocity triangles; stage power and work and use of the Euler equation, stage flow and temperature rise coefficients

Primary (boundary layer) losses and secondary (corner, blade tip) losses, pressure loss coefficient

Compressor performance characteristics and mapping: stage matching; overall pressure ratio against inlet mass flow function maps, the working line, stability line and stability margin

Compressor operating problems outside limits; mild and deep surge, blade stall and flutter, methods of control.

Fans:

High bypass; functions and mechanical design of fan blades, disc and casing, interaction as part of the compression system; military use low bypass fans, function and configuration of fan rotor blades, discs and blisks, fan casing and guide vanes.

Centrifugal compressors:

Modern usage and design configuration; functions of impeller, rotating guide vanes, diffuser vanes and casing; operating principles, pressure and velocity changes through compressor.

Turbines:

Turbine: types impulse, reaction and impulse-reaction; functions and configuration

Aerodynamic operation and performance: turbine geometry, use of velocity triangles, axial velocity against blade speed, changes in whirl velocity across stage, mass flow, power calculations, efficiency contours, blades and nozzle guide vanes (NGV)

Turbine design methodology: mechanical design of discs, blade attachments and blades to meet; aerodynamic requirements, mechanical and thermal stresses, vibration, fatigue and creep requirements

Turbine disc, blade and NGV cooling methods, coatings and materials.

LO3 **Develop an evaluation of the design and performance of aircraft gas turbine engine intake, combustion and exhaust modules**

Air intakes:

Types, circular, asymmetrical, external compression, variable geometry, supersonic

Intake aerodynamic performance: ideal and real airflow behaviour, flow through intake under static, climbing and high speed conditions; flow matching and loss characteristics

Design and performance: air velocity control to compressor, use of variable geometry design; aerodynamic performance and design features of subsonic high bypass fan; throat sizing, lip sizing, diffuser design; airframe intake integration, nacelle and cowling design features.

Combustion systems:

Combustor types and design architecture: multiple combustion chamber, tubo-annular, annular; fuel injector vaporisers and fuel spray nozzles

Combustor performance: diffuser performance and stability, dilution zone performance, dilution zone mixing performance

Combustion losses and efficiencies: performance criteria, efficiency of combustion, system pressure losses and losses due to dissociation, outlet temperature distribution, stability and light-up limits

Flame stabilisation: definition and measures of stability performance; factors controlling stability, fuel type, fuel-air-ratio, gas velocity, temperature and pressure, flame holder size and shape.

Exhausts:

Function, design and operational performance of jetpipe nozzles, thrust reversers, after burners; directional and velocity control of hot and cool gas flows; thrust control and augmentation performance; noise reduction methods.

LO4 **Investigate the factors affecting the design, performance and environmental impact of gas turbine powered aircraft operation.**

Design and performance:

Measures of performance including: specific thrust = output thrust/engine inlet mass flow, specific power = output power/engine inlet mass flow, specific fuel consumption (sfc) = fuel flow rate/output thrust or power, where sfc is measured in kilogrammes of fuel burnt per hour per Newton of thrust or kg/hr/N

Effect of gas turbine cycle parameters on performance: effect of compressor pressure ratio and turbine entry temperature (TET) on sfc, specific thrust and power

Off-design performance: effects on gross thrust and momentum drag with Mach number for turbojet and turbofan engines

Effect and implications of thermal and propulsive efficiency on aircraft specific fuel consumption and thrust performance of turbojet and high bypass turbofan aircraft

Combustion design and performance: methods used to ensure high combustion efficiency, flame stability, minimisation of pressure losses and low emissions

Thrust enhancement including use of variable area nozzles, reheat, water and water/methanol

Design trade-offs between gas turbine engine production and operating costs, performance and effects on the environment.

Environmental impact:

Noise measurement and limits including decibel (dB) rating, noise limit regulation

Sources of aircraft noise and its reduction including fan, exhaust jet, low-pressure turbine and combustor noise, turbine engine noise testing

Nature and effects on the environment of gas turbine operating emissions including: health risks from global warming and acid rain, carbon dioxide (CO_2), water vapour (H_2O), contrails and the production of (H_2O) and sulphuric acid (H_2SO_4), carbon monoxide (CO), oxides of nitrogen (NO_x) and sulphur (SO_x), and smoke particulates

Airport pollution, including noise and emissions monitoring and the effect of the introduction of the standard landing and take-off cycle (LTO)

Modern gas turbine emission reduction methods, including the control of unburnt hydrocarbons and carbon monoxide (CO), improvements in combustor design, use of high bypass turbofan engines, relationship of top turbine temperature (TTT), engine performance and the production and control of oxides of nitrogen (NO_x)

Review future design innovations to reduce environmental pollution: development of more electric engines, use of smart and lighter materials, reduction in fuel burn, introduction of non-hydrocarbon fuels, improvements in engine/airframe integration.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine gas turbine engine performance, using thermo-fluid principles and propulsion cycle efficiencies		
P1 Determine how thermo-fluid principles contribute to the operation of aircraft gas turbine propulsion cycles. **P2** Explore turbojet, turboprop and turbofan propulsion cycles to predict engine performance.	**M1** Illustrate how thermo-fluid principles and turbojet, turboprop and turbo fan propulsion cycles are used to predict engine performance.	**D1** Apply thermo-fluid principles and turbojet, turboprop and turbofan propulsion cycles and component efficiencies to predict engine performance in given examples.
LO2 Evaluate the design and performance of aircraft gas turbine engine turbomachinery		
P3 Evaluate the design configuration, aerodynamic operation and performance characteristics of axial flow and centrifugal compressors and fan modules. **P4** Compare the types, mechanical design, operation and performance characteristics of turbine modules.	**M2** Explore the design and aerodynamic and thermo-fluid operation of axial and centrifugal compressors, fan and turbine modules, and their components, to show the contribution made by each module to engine performance.	**D2** Analyse the design of axial and centrifugal compressors, fans and turbine modules and their components and their contribution to engine performance, and suggest ways of improving performance.
LO3 Develop an evaluation of the design and performance of aircraft gas turbine engine intake, combustion and exhaust modules		
P5 Develop an evaluative review of the types, functions and design features that aid the aerodynamic and thrust performance of air intakes and exhausts. **P6** Discuss the types of combustion methods and design features of combustion systems and their components, that aid engine performance.	**M3** Illustrate the design features and aerodynamic and thermo-fluid operation of air intake, combustion and exhaust modules and their components, stipulating the contribution made by each module to thrust production and overall engine performance.	**D3** Critically evaluate the design features and aerodynamic and thermo-fluid operation of air intake, combustion and exhaust modules and their components to assess areas for performance improvement.

Pass	Merit	Distinction
LO4 Investigate the factors affecting the design, performance and environmental impact of gas turbine powered aircraft operation		
P7 Discuss how gas turbine engine performance is measured and how, through better design, improvements in thrust production, fuel efficiency and emissions are achieved in gas turbine engines. **P8** Investigate the nature of environmental noise and emissions produced from gas turbine engines and the methods used to mitigate their effects.	**M4** Demonstrate how gas turbine engine performance is improved and the production of environmental noise and emissions is reduced through better design features, improved materials and operating procedures.	**D4** Critically evaluate how gas turbine engine performance may be improved and how reductions in environmental noise and emissions may be achieved through better design and improved materials and operating procedures.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Cumpsty N. and Heyes A. (2016) *Jet Propulsion − A simple guide to the aerodynamic and thermodynamic design and performance of jet engines*. 3rd Ed. Cambridge University Press.

El-Sayed A.F. (2017) *Aircraft Propulsion and Gas Turbine Engines*. 2nd Ed. CRC Press.

Giampaolo T (2020) *Gas Turbine Handbook − Principles and Practice*. 5th Ed. River Publishers.

Gudmundsson S. (2020) *General Aviation Aircraft Design − Applied Methods and Procedures*. 2nd Ed. Butterworth-Heinemann.

Royce R. (2015) *The Jet Engine.* 5th Ed. John Wiley & Sons.

Sadraey M.H. (2023) *Aircraft Performance an Engineering Approach*. 2nd Ed. CRC Press.

Saravanamuttoo H. I. H., Rogers G. F. C., Cohen H. and Straznicky P. V. (2009) *Gas Turbine Theory*. 6th Ed. Pearson.

Sterkenburg R. and Wang P.H. (2022) *Standard Aircraft Engines Handbook*. 1st Ed. McGraw-Hill.

Tooley, M. and Dingle, L. (2012) *Engineering Science, Part III*. Routledge.

Wild T.W. and Davis J.M. (2023) *Aircraft Powerplants: Powerplant Certification.* 10th Ed. McGraw-Hill.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Combustion in Aircraft gas Turbine Engines

Gas Turbine Engine – Towards the Future of Power

Journal of Aircraft

Journal of Engineering for Gas Turbines and Power

Journal of Propulsion and Power

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 5005: Further Thermodynamics

Unit 5028: Aircraft Structural Integrity.

Unit 5031: Advanced Composite Materials for Aerospace Applications

Unit Code: K/651/0893

Level: 5

Credits: 15

Introduction

Over the past three decades, the use of advanced composite materials in aircraft primary structures has increased significantly. Driven by the demand for fuel-efficient, lightweight and high stiffness structures that have fatigue durability and corrosion resistance, modern large commercial aircraft are designed with more than 50% composite materials. Despite the many advantages, composite structural certification becomes challenging due to the lack of experience in large- scale structures, complex interactive failure mechanisms, sensitivity to temperature and moisture, and scatter in the data, especially regarding fatigue.

This unit explores the advantages and the complexities of designing components with advanced composite materials and will provide an insight into the requirements and testing of aerospace composite structures.

On successful completion of this unit students will be able to evaluate a composite design for manufacture, calculate the mechanical properties of composite materials, explain their failure mechanisms, describe environmental degradation of materials, explain post-consumer recycling issues and evaluate new sustainable materials for aerospace use.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Evaluate composite designs for manufacture

LO2 Appraise the mechanical properties of composite materials

LO3 Synthesise assessment of the failure mechanisms of aerospace composite materials

LO4 Critique environmental effects on aerospace composite materials, post-consumer disposal issues and the future of sustainable composites in aerospace.

Essential Content

LO1 **Evaluate composite designs for manufacture**

Tooling:

Different tooling materials used and the relative merits such as cost and longevity. Key tooling features, including the importance of draft angles. Appropriate tooling for a range of composite designs using simple as well as complex multi-part tooling.

Materials:

Appropriate material for a composite design, taking into account the types of material fibres, tows, bundles and yarns available used and how they affect material properties, including fibre volume fractions

Manufacturing properties of different materials, including material drape, gapping, inter-yarn slippage and buckling, and how these can affect the properties of the final component

Process required for material qualification for flight approval and the associated timescales and costs.

Modelling:

CAD model used to predict material response under load, provide aeroelastic tailoring and show fibre paths. CAD/CAM model to show how a composite design can be manufactured efficiently.

Finishing processes:

Tooling design to minimise the finishing processes required on a component, machining, drilling, sanding, cutting, etc.

LO2 **Appraise the mechanical properties of composite materials and structures**

Elastic properties of a ply:

Equations for predicting ply properties and the differences between anisotropic and unidirectional lamina.

Laminate properties:

Laminate stiffness matrix for a composite laminate using classical laminate plate theory (CLPT) with associated calculations. Structural couplings in various types of composite laminates (e.g. symmetric, anti-symmetric, balanced) using the CLPT-derived stiffness matrix. CLPT to determine stresses in plies for simple loading conditions.

Mechanical properties:

Calculations, backed up by testing, of tensile strength, compressive strength, shear strength and elastic response.

Matrix properties:

Effects on the finished material of altering cure cycle parameters, including rheology of thermoset resins, mixtures rule, glass transition temperature and post curing. Cure cycle for a material.

Composite properties:

Sizing and resin compatibility

Calculations of interfacial bonding and shear strength; how environmental factors can affect bond strength

A range of composite materials, including MMC and CMC; the coefficient of thermal expansion, thermally induced stresses and the effect on strength.

LO3 **Synthesise assessment of the failure mechanisms of aerospace composite materials**

Failure mechanisms:

Fracture toughness for different composite materials using a range of techniques including Griffiths model and Weibull distribution, notch strength and sensitivity

Fatigue properties of composites and metals: fatigue and endurance limits, defect sensitivity. Fatigue testing of composite aerospace components and structures.

Failure modes:

A variety of failure modes within composite materials, effect on mechanical properties: matrix failure, fibre failure, delamination, debonding, fibre pull out.

Life prediction:

The life of critical aerospace components, calculations using data from testing. use of test results to calculate safe life, including the use of factors.

LO4 **Critique environmental effects on aerospace composite materials, post-consumer disposal issues and the future of sustainable composites in aerospace.**

Environmental effects:

Effects of environmental conditions on composite material properties and associated testing: hydrothermal sensitivity, creep, UV, lightning strike, fuels and aerospace fluids and chemicals.

Protections:

Selection of correct protective methods for composite materials in a range of situations. Future advances in composite coatings.

Post-consumer disposal:

Process of post-use disposal of composite aerospace components, considering cost, protection of intellectual property and recyclability.

Sustainable composites:

Sustainable composites as an alternative to traditional materials. Method for analysing alternative materials for use in aerospace, considering: mechanical properties, process suitability, environmental effects and aerospace qualification requirements.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate composite designs for manufacture		
P1 Explain the design philosophy of composite structures and how using CAD/CAM can minimise finishing processes. **P2** Evaluate the various types of tooling materials commonly used and any three types of tooling features used in aerospace composite manufacture.	**M1** Compare the drape characteristics of four reinforcements detailing the restrictions and subsequent effect on manufacture methods.	**D1** Critique how modelling is used to predict mechanical responses of structures, including discussions on aeroelastic-tailoring predictions.
LO2 Appraise the mechanical properties of composite materials		
P3 Differentiate between tensile strength, transverse strength, compression strength, shear strength and flexural strength of polymer composite materials. **P4** Appraise elastic properties of fibre composites, acknowledging the effect of fibre length.	**M2** Analyse stresses in a composite laminate using classical laminate plate theory, with an explanation of the significance of laminate couplings.	**D2** Evaluate cure monitoring and how it can be used to calculate exact mechanical properties of polymer composites, including the effects of post-curing.

Pass	Merit	Distinction
LO3 Synthesise assessment of the failure mechanisms of aerospace composite materials		
P5 Differentiate between the identified causes of tensile failure, longitudinal failure, compressive failure, interlaminar shear failure and fatigue failure of PMC, CMC and MMC. **P6** Synthesise testing results with an assessment of how the results are used to calculate the safe life of an aerospace component.	**M3** Critically evaluate crack growth both at microstructural level and macroscopic level in PMCs, MMC and CMCs.	**D3** Show how the toughness of a composite is theoretically calculated.
LO4 Critique environmental effects on aerospace composite materials, post-consumer disposal issues and the future of sustainable composites in aerospace.		
P7 Evaluate lightning strike protection strategies for composite aircraft. **P8** Critique environmental effects on aerospace composites and how coatings and paints are used to counteract these effects.	**M4** Critically analyse the issues with post-consumer disposal of aerospace structures, paying particular attention to the issues around intellectual property of design.	**D4** Investigate the sustainable materials currently being produced for aerospace by comparing these with traditional aerospace composites.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Carrera E. (2016) *Composite Materials and Structures in Aerospace Engineering*. Trans Tech Publications.

Dorworth, L. C., Gardiner G. L., and Mellema G. M. (2009) *Essentials of Advanced Composite Fabrication & Repair.* Aviation Supplies and Academics, Inc.

Gay D. (2014*) Composite Materials: Design and Applications*. 3rd Ed. Boca Raton, Florida: CRC Press.

Giurgiutiu V. (2022) *Stress, Vibration, and Wave Analysis in Aerospace Composites – SHM and NDE Applications*. 1st Ed. Elsevier.

Guha P. (2022) *Composites Innovation: Perspectives on Advancing the Industry*. 1st Ed. CRC Press.

Harris B. (1999) *Engineering Composite Materials*. 2nd Ed. London: Maney Publishing

Hull D. and Clyne T. W. (2019) *An Introduction to Composite Materials*. 3rd Ed. Cambridge: Cambridge University Press.

Jawaid M. and Thariq M. (Editors) (2018) *Sustainable Composites for Aerospace Applications*. 1st Ed. Elsevier.

Jones R. M. (2018) *Mechanics of Composite Materials*. 2nd Ed. CRC press.

Lin K. Y. (2015) *Composite Materials: Materials, Manufacturing, Analysis, Design and Repair*. 2nd Ed. CreateSpace Independent Publishing Platform.

Matthews F. L. and Rawlings R. D. (1999) *Composite Materials: Engineering and Science.* Cambridge: Woodhead Publishing.

Rana S. and Fangueiro S. (2016) *Advanced Composite Materials for Aerospace Engineering: Processing, Properties and Applications*. Woodhead Publishing.

Sultan M.T.H., Rajesh M. and Jayakrishna K. (2022) *Repair of Advanced Composites for Aerospace Applications.* 1st Ed. CRC Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Advanced Aerospace Composite Materials

Aerospace: Advanced Composite Materials

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

American Journal of Aerospace Engineering

International Journal of Aerospace Engineering

International Journal of Aviation Science and Technology

Journal of Aircraft

Journal of Aerospace Engineering

SAE International Journal of Aerospace

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4044: Composite Materials for Aerospace Applications
Unit 5029: Avionic Systems.

Unit 5032: Advanced Turbine Rotary Wing Aircraft Mechanical and Flight Systems

Unit Code: **L/651/0894**

Level: **5**

Credits: **15**

Introduction

Since the conception of the idea of flight, rotary wing heavier-than-air flying machines have been considered. For example, Leonardo da Vinci created the 'Helical Air Screw' at the turn of the 16th century. It is believed that although the airscrew was built, it never flew due its very poor lift-to-weight ratio. At the turn of the 20th century, the early pioneers of flight built and attempted to fly a number of rotary wing aircraft. Some failed in spectacular style; however, some actually achieved limited flight. The development of the rotary wing aircraft we see today started in the 1940s and then rapidly advanced in the 1950s and 60s.

These early aeronautical engineers had to overcome many significant differences between principles of flight for fixed wing and rotary wing aircraft. The nature of the rotary winged aircraft creates many diverse fluid flows, physical gyroscopic effects and dissymmetry of lift and torque reactions, to name a few of the aerodynamic differences.

This unit introduces students to the atmosphere in which rotary wing aircraft operate in, the scientific principles that underpin flight theory, how the aerodynamic forces are generated throughout all phases and transitions of rotary wing flight. It also includes the specific design features that are essential to maintain stability and directional control.

On successful completion of this unit students will be able to develop subject related competencies on the properties of the atmosphere relating to rotary wing flight and aerodynamic principles and apply them to aircraft flight; the generation, nature and effects of aerodynamic forces during flight; the key design features that control and maintain airflows around a rotary wing aircraft; and the nature and methods used to stabilise and control rotary aircraft.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explore standard atmospheric properties and aerodynamic principles affecting flight of a rotary winged aircraft

LO2 Illustrate the nature and effect of forces of rotary wing aircraft directional flight control

LO3 Explore rotary wing aircraft directional flight control

LO4 Investigate the nature of different rotary winged aircraft design variations and features.

Essential Content

LO1 **Explore standard atmospheric properties and aerodynamic principles affecting flight of a rotary winged aircraft**

The standard atmosphere:

The composition of the air and different layers of the real atmosphere

Nature of the International Standard Atmosphere (ISA); need, function, definitions of standard properties

Use of tables and hydrostatic, temperature lapse rate and state equations to determine the changing parameters (temperature, pressure, density, viscosity) of the air in the ISA, with changing altitude.

Aerodynamic principles:

Airflow definitions: laminar, turbulent, compressible, and incompressible flows

Nature of low speed airflow over aerofoil sections; aerofoil terminology, viscosity effects, boundary layer, aerodynamic shape, pressure and flow changes with differing angle of attack (AOA) and airspeeds

Determine experimentally and analytically lift ($L=C_L 1/2\rho V^2 S$) and drag ($D=C_D 1/2\rho V^2 S$) forces over aerofoil sections subject to low speed airflows, how lift and drag forces interact over aircraft wings and the significance of the lift/drag ratio as a measure of performance

Define and use the continuity, energy, Bernoulli, isentropic and Reynolds number fluid flow equations to determine low speed airflow parameters

Nature of airflows, generated lift and drag created by the main and tail rotor blades.

LO2 **Illustrate the nature and effect of forces of rotary wing aircraft directional flight control**

Rotational and aerodynamic forces acting on rotary wing aircraft:

Define rotation effects of gyroscopic precession and rigidity

The effects of gyroscopic and lift/drag force generation

Rotor blade geometric twist, flapping/coning, tip path plane, lead and lag

Ground effect, ideal wake, Blade loading, vortex ring state.

LO3 **Explore rotary wing aircraft directional flight control**

Rotary wing aircraft control:

The use of gyroscopic precession effect in control of a rotary wing aircraft in the six planes of movement

Aerodynamic force and the pendulum effect in control of a rotary wing aircraft in the six planes of movement

Relevant case studies including use of latest digital technologies (i.e., Aviation 4.0) in rotary wing aircraft control.

Nature of flight forces and airflow:

The nature of main rotor lift and drag forces whilst a helicopter is in the hover, transitional and forward flight

Momentum theory for hover and climb ($T = m\Delta V$)

Determine gravitational and aerodynamic forces during straight and level flight, steady coordinated turn, ascending and descending flight

The lift and drag force parameters, autorotational flight.

LO4 **Investigate the nature of different rotary winged aircraft design variations and features**

Design features:

Development of the main rotor blade and tail rotor design. Example case studies include the British Experimental Rotor Project (BERP)

Usage and benefits of twin counter rotating main rotors

Rotary wing aircraft tail planes and other external aerodynamic design features.

Other types of rotary wing aircraft:

Tilt rotor aircraft and Autogyro helicopters.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore standard atmospheric properties and aerodynamic principles affecting flight of a rotary winged aircraft		
P1 Discuss the nature of the ISA and the changes that take place to the properties of the air with changing altitude. **P2** Illustrate, using theoretical calculations and experimental results, how lift and drag forces are generated from low speed airflows over aerofoil sections. **P3** Explore the nature of the airflow, lift, and drag generation created by a helicopter's main and tail rotor blades.	**M1** Analyse quantitatively how the properties of the air in the ISA change with altitude and the differences between the lift and drag forces found from theoretical calculations and experimental results.	**D1** Evaluate the properties of the air in the ISA with changing altitude, and the relationship between fluid flow equations and the generation of lift and drag affecting flight.
LO2 Illustrate the nature and effect of forces of rotary wing aircraft directional flight control		
P4 Demonstrate how gyroscopic precession and lift differentials can be used to control a rotary winged aircraft in flight. **P5** Illustrate the aerodynamic and airflow effects created by the rotor blades of a rotary winged aircraft.	**M2** Assess, using theoretical calculations, the nature of flight forces during manoeuvres and how these forces are affected by geometrical and external factors.	**D2** Appraise the effect and nature of flight forces on a rotary wing aircraft's airframe throughout all phases and conditions of flight, including the nature and significance of the load and horizontal and vertical velocity limits.

Pass	Merit	Distinction
LO3 Explore rotary wing aircraft directional flight control		
P6 Explore the use of the gyroscopic precession effect in the control of a rotary wing aircraft in the six planes of movement. **P7** Describe generation of the lift force, control, and aerodynamic limitations of an Autogyro helicopter.	**M3** Illustrate, using vector representation, the application of aerodynamic forces and the pendulum effect in control of a rotary wing aircraft in the six planes of movement.	**D3** Evaluate through analytical methods the power required to allow a helicopter to maintain altitude in a hover.
LO4 Investigate the nature of different rotary winged aircraft design variations and features		
P8 Investigate the development of the main rotor blade and tail rotor design, including the British Experimental Rotor Project (BERP). **P9** Show how the aerodynamic use of rotary wing aircraft tail planes and other external aerodynamic design features **P10** Discuss the flight characteristics of 'tilt rotor' and Autogyro rotary aircraft.	**M4** Explore counter rotating twin rotor helicopter aerodynamic control and stabilisation.	**D4** Critically analyse the aerodynamic properties of the BERP main rotor blade and evaluate the advantages and disadvantages of the design.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson Jr J. D. (2016) *Introduction to Flight*. 8th International Student Ed. McGraw-Hill.

Barnard R. H. and Philpott D. R. (2010) *Aircraft Flight*. 4th Ed. Pearson.

Delaurier J (2022) *Aircraft Design Concepts – An Introductory Course*. 1st Ed. CRC Press.

Dingle L. and Tooley M. (2013) *Aircraft Engineering Principles*. 2nd Ed. Routledge.

Kuzmanovski Z.M. (2023) *The World of Helicopters*. Kindle Ed.

Megson T.H.G. (2021) *Aircraft Structures for Engineering Students.* 7th Ed. Butterworth-Heinemann.

Padfield G.D. (2018) Helicopter Flight Dynamics: Including a Treatment of Tiltrotor Aircraft. 3rd Ed.

Ricci S., Concilio A., Aliabadi F.M.H., Dimino I., Botez R., Lecce L., Semperlotti F. and Pecora R. (Editors) (2017) *Morphing Wing Technologies – Large Commercial Aircraft and Civil Helicopters.* 1st Ed. Butterworth-Heinemann.

Seddon J. (2011) *Basic Helicopter Principles*. 3rd Ed. Wiley.

Wagtendonk, W. J. (2007) *Principles of Helicopter Flight*. 2nd Ed. Aviation Supplies & Academics.

Bramwell A. R. S., Balmford, D. and Done G. (2001) *Bramwell's helicopter dynamics*. Elsevier.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

The Aeronautical Journal

Aerospace

The Journal of American Helicopter Society

Rotor and Wing International

Links

This unit links to the following related units:

Unit 4041: Aircraft Aerodynamics

Unit 4045: Turbine Rotary Wing Mechanical and Flight Systems.

Unit 5033: Nuclear Reactor Operations

Unit Code: D/615/1540

Level: 5

Credits: 15

Introduction

The safe and effective operation of a nuclear power plant relies on four fundamental requirements: (i) control of the fission chain reaction and hence power generation; (ii) maintenance of adequate heat removal from the reactor, thus preventing over-heating; (iii) maintaining effective protective measures against the hazards of radiation in routine and accident conditions; and (iv) maintaining appropriate chemical and material controls to protect against corrosion or other forms of environmental degradation of reactor components.

The purpose of this unit to provide students with a clear understanding of how these requirements, (i), (ii) and (iii), are met in a modern nuclear power reactor and, more specifically, the role of operating staff in operating and maintaining the plant in a safe and effective manner. Note that the chemistry of nuclear reactors is the subject of a separate unit. The topics addressed in this unit are directly relevant for control room and reactor system operators, maintenance technicians and radiation protection technicians.

Much of the material in this unit has been aligned with guidance issued by the Institute of Nuclear Power Operations (INPO) and, in particular, the Uniform Curriculum Guide for Nuclear Power Plant Technician, Maintenance and Non-Licensed Operations Personnel Associate Degree Programmes; ACAD 08-006 (April 2011) published by the National Academy for Nuclear Training (NANT).

Topics included in this unit include: physics of the fission process and the neutron-induced fission chain reaction; physics aspects of reactor operations covering start-up, at-power operation and shut-down; thermal-hydraulic aspects of reactor operation, focusing on heat removal from the core and the importance of thermal limits; radiation hazards and controls during normal operations and accident conditions.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Apply physics analysis to understand the fission chain reaction and how it is controlled in a nuclear reactor

LO2 Show how thermal-hydraulic analysis is used to understand the heat removal process in a nuclear reactor and the means of maintaining heat removal capability

LO3 Apply physics and thermal-hydraulic analysis to model aspects of reactor operation during start-up, sub-power operation, operation at power and shut-down

LO4 Analyse the processes that generate radiation and radioactivity in a nuclear reactor and explain how these are controlled.

Essential Content

LO1 **Apply physics analysis to understand the fission chain reaction and how it is controlled in a nuclear reactor**

Nuclear reactions and fission:

Types of reaction; definition of cross section and units; definition of neutron flux and units; interaction of neutrons with nuclei; elastic and inelastic scattering (qualitative treatment); absorption; radiative capture and transmutation

Derivation and application of three-factor formula for reaction rates; mechanics and energetics of fission process; products of fission and their significance; derivation and application of formula linking fission rate and power density.

The fission chain reaction:

Fast and thermal neutrons; neutron moderation; moderator effectiveness (qualitatively); neutron life cycle; neutron lifetime; neutron multiplication factor; fast fission; fast leakage; resonance absorption; thermal leakage; fuel utilisation; thermal reproduction; derivation and application of six-factor formula for neutron multiplication factor; neutron balance equation; conditions for criticality – geometric and material composition aspects; neutron flux and power profiles (qualitatively); power peaking; flux flattening using neutron reflectors; zoned fuel; fixed absorbers; coolant flow path.

Reactor kinetics:

Definition of reactivity; prompt and delayed neutrons; significance of delayed neutrons in reactor control; response to reactivity addition without and with delayed neutrons; derivation of simple first-order exponential equation for neutron variation with time; reactor period, doubling time, start-up rate; consequences of excessive reactivity addition; prompt criticality.

Reactivity control in nuclear reactors:

Neutron absorbers and their role in reactivity control; control rods – typical design and operational characteristics; chemical methods of reactivity control (boric acid); relationship between boric acid concentration and reactivity; reactivity control in a PWR and reactor protection; temperature effects on reactivity; transient fission product poisons and their effect on reactivity (Xe135); mathematical modelling of through-life reactivity effects; fuel burn-up; permanents poisons; burnable poisons; derivation and application of through-life reactivity equations; impact of refuelling cycle; fuel life limitation.

LO2 **Show how thermal-hydraulic analysis is used to understand the heat removal process in a nuclear reactor and the means of maintaining heat removal capability**

Thermal hydraulics of heat removal in a PWR:

Heat transfer processes (conduction, convection and radiative); conduction (Fourier's Law); heat conduction coefficient; convection (Newton's Law of Cooling); convection coefficient; material properties related to heat transfer; core power distribution; neutron flux and power density profiles; power peaking factors; volumetric, surface and linear heat rates and interrelationships; mathematical modelling of heat removal from PWR fuel pins by conduction and convection; calculation of fuel pin temperature profile; whole core heat removal; calculation of axial temperature profiles for fuel, clad and coolant; impact of coolant flow rate on temperature profiles.

Thermal limits: design considerations and operational constraints:

Thermal limits related to fuel and clad temperature; operating limits; thermal limits related to critical heat transfer; boiling heat transfer; types of boiling: nucleate, pool and flow boiling; departure from nucleate boiling (DNB); critical heat flux; operating limits related to DNB.

LO3 **Apply physics and thermal-hydraulic analysis to model aspects of reactor operation during start-up, sub-power operation, operation at power and shut-down**

Physics aspects of reactor operation:

Shut-down reactor; shut-down reactivity margin; reactor start-up; approach to critical; sub-critical multiplication factor; effect of neutron sources; source and source-free criticality; the sub-power reactor; vulnerabilities and associated protection systems; power reactor; self-regulating and load following characteristics; vulnerabilities and associated protection systems; shutting down the reactor; response to reactor scram; decay (residual) heat – sources; significance and removal.

Thermal-hydraulic aspects of reactor operation:

Primary circuit design; design and operation of main coolant pumps; design and operation of pressuriser, importance of avoiding boiling; saturation curves; critical point

Steam generator (boiler) design and operation; superheated and super-saturated steam; steam quality; steam tables; thermodynamic cycles and efficiency; Rankine steam cycle; steam turbine design and operation; turbine efficiency; moisture and steam quality effects; role and function of condenser, re-heaters, feedwater heaters, feedwater pumps and moisture separators in PWR thermodynamic cycle.

LO4 **Analyse the processes that generate radiation and radioactivity in a nuclear reactor and explain how these are controlled.**

Source of radiation and controls measures in a nuclear reactor:

Direct radiation from the operating reactor (neutron and gamma radiation fields); shielding arrangements; direct radiation from shut-down reactor and shielding arrangements; radiation from activation of primary coolant; mathematical modelling of neutron and gamma shielding; shielding calculations for simple geometries; neutron and gamma radiation measurement and survey techniques.

Activation processes in control of contamination in nuclear reactors:

Neutron activation process; neutron activation calculations; activation of primary coolant; primary coolant treatment to minimise activation and remove activated products; importance of primary circuit chemistry control in minimising activation and worker doses; activation of components and reactor surroundings; radiation and contamination controls during maintenance and outages; radioactive effluents (liquid and gaseous) and treatment prior to discharge; radiation hazards associated with used fuel in at-reactor cooling ponds.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply physics analysis to understand the fission chain reaction and how it is controlled in a nuclear reactor		
P1 Calculate the reactivity of a simple homogeneous reactor of specified dimensions and composition using standard physics analysis.	**M1** Calculate and explain the variation in reactivity of a homogeneous reactor with core age as the composition changes.	**D1** Critically assess the limitations of the diffusion theory approach used in reactor physics and make recommendations on how modelling could be improved to provide more realistic predictions.
LO2 Show how thermal-hydraulic analysis is used to understand the heat removal process in a nuclear reactor and the means of maintaining heat removal capability		
P2 Calculate temperature using thermal-hydraulic analysis profiles in the core of a reactor operating at a steady state.	**M2** Compare calculated temperature profiles with thermal limits and determine the maximum power generation.	**D2** Critically assess the limitations of mathematical models based on first-order single-phase thermal-hydraulic processes and make recommendations on how the modelling could be improved to provide more realistic predictions.

Pass	Merit	Distinction
LO3 Apply physics and thermal-hydraulic analysis to model aspects of reactor operation during start-up, sub-power operation, operation at power and shut-down		
P3 Use mathematical models of the physics and thermal hydraulics of a reactor to explain and predict critical aspects of reactor operation.	**M3** Use mathematical models of the physics and thermal-hydraulic behaviour of the reactor to estimate advanced key parameters including maximum power and reactivity.	**D3** Extend the mathematical model of the physics and thermal hydraulics of the reactor to consider all through-life effects – and use the extended model in an optimisation analysis balancing core power and core life.
LO4 Analyse the processes that generate radiation and radioactivity in a nuclear reactor and explain how these are controlled.		
P4 Analyse the sources of radiation and radioactivity in an operating PWR.	**M4** Calculate levels of radiation and activation in an operating PWR.	**D4** Develop quantitative models to predict the radiation levels and the build-up of radioactivity in a reactor plant, apply the models to all operating states of the reactor, assess the limitations of the modelling and make recommendations on how the modelling can be made more realistic.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Fulcher, M. (2015) *Nuclear Reactor Thermal Hydraulics*. New Delhi: ML Books International.

Knief, R. A. (1992) *Nuclear Engineering.* Carlsbad: Hemisphere.

Lamarsh, J. R. and Baratta, A. J. (2001) *Introduction to Nuclear Engineering*. 3rd Ed. London: Pearson.

Pitts, D. and Sissom, L. E. (2012) *Heat Transfer*. 2nd Ed. New York: McGraw-Hill.

Zahouri, B. and Fathi, N. (2015) *Thermal Hydraulic Analysis of Nuclear Reactors*. New York: Springer.

Websites

http://www.nrc.gov/	United States Nuclear Regulatory Commission Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Pressurized Water Reactors (Report)

Links

This unit links to the following related units:

Unit 5033: Nuclear Reactor Operations

Unit 5034: Nuclear Reactor Chemistry

Unit 5037: Nuclear Fuel Cycle Technology.

Unit 5034: Nuclear Reactor Chemistry

Unit Code: **H/615/1541**

Level: **5**

Credits: **30**

Introduction

Understanding the chemistry, anticipating chemical changes and controlling chemical processes are central to the safe and efficient operation of a nuclear power plant. Past evidence has shown that failure to predict and monitor plant chemistry leads to expensive repairs, long periods of shut-down and, in some cases, unsafe conditions – all of which are avoidable.

In water-cooled reactors, in particular, chemical interactions between the coolant and the various metal components making up the cooling circuits are of major importance. Corrosion can occur in many different forms and has many deleterious effects. Uncontrolled corrosion weakens structures and could lead to coolant circuit failure and consequent core damage. Corrosion can also lead to fouling and possible blockages in the cooling circuit which reduces the effectiveness of heat transfer and renders the plant less efficient.

In addition to controlling the chemistry of the cooling circuits, it is important to understand the chemical changes which take place inside the nuclear fuel during the fission process. Optimising nuclear fuel performance means extracting the maximum possible energy from the material while maintaining safe operating margins. To achieve this, chemists must understand the process of fission product generation inside the fuel and predict the impact of fission products on fuel behaviour. In addition, in the event of fuel pin failure, the chemist must be able to predict releases of radioactive fission products into the surrounding coolant and ensure that appropriate monitoring and radiation protection processes are in place and effective.

The purpose of this unit is to provide students with a clear understanding of the chemistry underlying nuclear reactor operations and enable them to describe, analyse and predict various changes and transitions that occur in the system. The focus of the unit will be on water-cooled reactors, the most common type of reactor used throughout the world. The chemistry of gas-cooled reactors is included, albeit in less detail.

Topics included in this unit are basic water chemistry and reactor water chemistry, water chemistry control, corrosion control, crud formation and the chemical composition of fresh and used nuclear fuel.

On successful completion of this unit students will be able to explain, measure and control the chemistry and chemical changes relevant to a nuclear reactor and advise on chemistry-related matters.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Show how the reactions of water, water chemistry control and reactor water treatments operate in relation to PWR reactors

LO2 Evaluate chemistry and chemical changes relevant to fresh and used nuclear fuel, fuel storage ponds and reactor coolants in PWR

LO3 Discuss the importance, formation, type and characteristics of corrosion and corrosion products and mitigation methods present in nuclear reactor cooling systems

LO4 Examine the techniques and methods used for coolant chemistry control in modern reactors.

Essential Content

LO1 **Show how the reactions of water, water chemistry control and reactor water treatments operate in relation to PWR reactors**

Revision of fundamentals of chemistry:

Units of measure, states of matter, elements and molecules, mixtures, solutions and compounds

The periodic table

pH: acids and bases

Conductivity

Ion exchangers

Properties and uses of gases.

Basic water chemistry control fundamentals:

Impurities, sources of impurities, ion exchange theory, parameters monitored (pH, conductivity, sodium, chlorides, fluorides, sulphates, hardness and silica), principles of water treatment, water chemistry control methods (ion exchange, O_2 control with hydrazine or N_2, pH control).

Reactor water chemistry fundamentals:

Control/removal of impurities (demineralisation, chemical addition, hydrogen addition, hydrazine, degassing), effect of impurities (increased corrosion rates, total gases, local radiation level), hydrogen gas in reactor water, radiolysis and recombination (water/ammonia), radiochemistry, sources of impurities (intrusion, ion exchange exhaustion), types of impurities (e.g. chlorides, fluorides, O_2 and H_2).

LO2 **Evaluate chemistry and chemical changes relevant to fresh and used nuclear fuel, fuel storage ponds and reactor coolants in PWR**

Nuclear fuel chemistry:

Radionuclides in fresh nuclear fuel

Radionuclides in irradiated nuclear fuel

Burn up.

Activation:

Water and impurity activation products

Activated corrosion products.

Fuel storage pond chemistry:

Volatile fission products

Corrosion processes and instant release factor

Radiation chemistry in reactor coolants.

LO3 **Discuss the importance, formation, type and characteristics of corrosion and corrosion products and mitigation methods present in nuclear reactor cooling systems**

Corrosion chemistry fundamentals:

Types, characteristics and prevention of corrosion.

Technical basis for the need to control the coolant chemistry of PWRs:

Material integrity and fuel integrity considerations in the reactor coolant system; radiation field control.

Corrosion products in PWR reactor systems:

Formation of corrosion products and dose rate concerns

Steam generator tubing.

Corrosion in AGR reactor systems:

Radiation-induced graphite oxidation, steel oxidation.

Crud formation and characteristics:

Crud composition, thickness and evaluation; crud elimination, crud mitigation.

LO4 **Examine the techniques and methods used for coolant chemistry control in modern reactors.**

Corrosion control using chemicals:

Ferrous alloy corrosion inhibitors (nitrites, molybdates and chromates), hydrazine, silicates, phosphates, copper alloy corrosion inhibitors.

Corrosion control without chemicals:

Corrosion control with Ph.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Show how the reactions of water, water chemistry control and reactor water treatments operate in relation to PWR reactors		
P1 Show how the basic phenomena concerning water and reactor water chemistry apply to water treatment in PWR.	**M1** Evaluate the effects of the various phenomena concerning water and reactor water chemistry and water treatment in PWR.	**D1** Calculate the effects of water and reactor water chemistry and relate these calculations to water and reactor water chemistry and the concepts behind water treatment in PWRs.
LO2 Evaluate chemistry and chemical changes relevant to fresh and used nuclear fuel, fuel storage ponds and reactor coolants in PWR		
P2 Evaluate the chemistry and chemical changes relevant to nuclear fuel, fuel storage ponds and reactor coolants in PWR.	**M2** Assess how the chemistry and chemical changes relevant to nuclear fuel, fuel storage ponds and reactor coolants in PWR provide a basis for developing corrosion preventative measures.	**D2** Calculate the chemical changes that occur in fuel storage ponds and use the results of these calculations to assess the effectiveness of strategies currently employed for fuel storage and cooling systems in PWRs.

Pass	Merit	Distinction
LO3 Discuss the importance, formation, type and characteristics of corrosion and corrosion products and mitigation methods present in nuclear reactor cooling systems		
P3 Discuss the basic formation mechanisms, types and characteristics of corrosion and corrosion products present in nuclear reactor cooling systems.	**M3** Show how calculations related to corrosion in a nuclear reactor can be used to predict the formation, type and characteristics of corrosion and corrosion products present in nuclear reactor cooling systems.	**D3** Critically evaluate the importance, formation, type and characteristics of corrosion and corrosion products and mitigation methods present in nuclear reactor cooling systems. Suggest possible corrosion prevention methods to be included in routine maintenance at a PWR nuclear site.
LO4 Examine the techniques and methods used for coolant chemistry control in modern reactors.		
P4 Examine the techniques and methods used for coolant chemistry control in modern reactors.	**M4** Discuss the various techniques and methods used for coolant chemistry control in modern reactors, and carry out calculations relevant to coolant chemistry control.	**D4** Critically examine the various techniques and methods used for coolant chemistry control in modern reactors, and identify the best techniques to complete particular measurements. Support choice with relevant calculations.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Choppin, G., Liljenzin, J-O., Rydberg, J. and Ekberg, C. (2013) *Radiochemistry and Nuclear Chemistry*. 4th Ed. Cambridge: Academic Press.

Neeb, K. H. (1997) *The Radiochemistry of Nuclear Power Plants with Light Water Reactors*. Berlin: de Gruyter.

Links

This unit links to the following related unit:

Unit 5036: Nuclear Reactor Materials.

Unit 5035: Nuclear Radiation Protection Technology

Unit Code: K/615/1542

Level: 5

Credits: 15

Introduction

Radioactive materials – and the radiations they emit – are used in a wide variety of industrial, medical and even domestic applications! However, the considerable benefits derived from the use of radiation must be weighed against the potential hazards, including risks to health in humans and potential impacts on the environment. It follows, then, that radiation protection measures must be implemented to ensure that all exposures are as low as reasonably achievable and, not surprisingly, there are strictly applied regulations covering all aspects of work with radiation.

The operation of nuclear power reactors is one industrial activity which gives rise to the generation of radioactive material and potential exposures to ionising radiations – during operation of the reactor, large amounts of radioactivity accumulate inside the nuclear fuel; in addition, radioactivity is generated in the reactor coolant and in some components close to the reactor core.

All nuclear power plants have dedicated Radiation Protection Advisers, Radiation Protection Supervisors and Radiation Monitors. Notwithstanding these specialist roles, all staff working in areas where they may be exposed to radiation are required by law to undergo specific training to ensure they understand the radiation hazards, regulatory requirements, protective measures and procedures adopted to ensure exposures are as low as reasonably practicable.

Topics included in this units are the fundamentals of radiation science (radioactivity and radiation, interaction of radiation with matter, radiation units and natural and human-made radiation in the environment), radiation principles and standards, radiation protection legislation in the UK, radiation detection and measurements, and internal and external radiation hazards.

The purpose of this unit is to provide students with an understanding of the properties of radiation, the hazards posed by exposure to radiation and the radiation protection principles and practices relevant to nuclear reactor operation. On successful completion, students should be able to interpret the advice of radiation specialists, formulate plans and radiation protection strategies in relation to their own workplace, and understand the rationale for rules, processes and procedures.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Apply knowledge of the science of radiation to design, implement and measure the effectiveness of radiation protection controls

LO2 Interpret radiation protection legislation and formulate management advice on radiation protection strategies in accordance with the relevant approved code of practice

LO3 Review radiation protection strategies in the workplace to ensure that radiation exposures are as low as reasonably practicable

LO4 Review the advice to relevant personnel on the effects of radiation exposure, radiation protection regulations and compliance procedures to personnel working in radiation environments.

Essential Content

LO1 **Apply knowledge of the science of radiation to design, implement and measure the effectiveness of radiation protection controls**

Radioactivity and radiation:

Modes of radioactive decay (alpha, beta, gamma, neutron, spontaneous fission)

Properties of radiations (nature, mass, charge)

Energetics of radioactive decay

Activity and activity units

Radioactive Decay Law (and applications), decay constant, half-life.

Interaction of radiations with matter:

Ionisation and excitation

Charged particle interactions, range-energy relationships for alpha, beta radiations

Bremsstrahlung radiation, annihilation of beta(+)

Gamma and X-ray interactions: photoelectric, Compton and pair production

Attenuation of gamma, X-ray: linear attenuation coefficient; half-value thickness

Neutron interactions: scattering, absorption; attenuation and absorption of neutrons

Neutron activation.

Radiation units:

Exposure, absorbed dose, equivalent dose, effective dose, committed effective dose

Definition of Gray, Sievert

Radiation and tissue weighting factors.

Biological effects of radiation exposure:

Basic human physiology

Interaction of radiation with cells

Deterministic effects of acute radiation exposure, dose-response relationship

Stochastic effects of chronic radiation exposure, dose-response relationship

Implications of the linear-no-threshold (LNT) model

Somatic and hereditary effects

Epidemiological evidence for radiation effects.

Natural and human-made radiation in the environment:

Cosmic radiation

Terrestrial sources

Naturally occurring radioactive material (NORM)

Radioactivity in the human body

Human-made environmental radiation: discharges, atmospheric bomb-tests

Summary of doses from natural and human-made sources of environmental (background) radiation.

LO2 **Interpret radiation protection legislation and formulate management advice on radiation protection strategies in accordance with the relevant approved code of practice**

Radiation protection principles and standards:

Justification, optimisation and limitation (examples of each)

The ALARP principle

Sources of international guidance (e.g. ICRP)

The system of dose limitation (employees, members of the public)

Dose limits for abnormal or emergency situations.

Radiation protection legislation in the UK:

Key requirements of Ionising Radiations Regulations (IRR 1999)

Key requirements of Environmental Permitting Regulations (EPR 2010)

Key requirements of Radiation Emergency Planning & Public Info Regulations (REPPIR 2001)

Key requirements pertaining to transport of radioactive materials (road, rail, air, sea).

LO3 **Review radiation protection strategies in the workplace to ensure that radiation exposures are as low as reasonably practicable**

Radiation detection and measurement:

General principles of radiation detection

Gas-filled detectors (ionisation chamber, proportional counter, Geiger counter)

Solid state detectors (scintillation detectors, semiconductor detectors)

Energy measurement and spectroscopy

Personal dosimeters (film, TLD, electronic).

LO4 **Review the advice to relevant personnel on the effects of radiation exposure, radiation protection regulations and compliance procedures to personnel working in radiation environments.**

External radiation hazards and protection measures:

Sources of external radiation

Protection using time, distance, shielding

Inverse square law (application and limitations)

Radiation shielding for alpha and beta radiation

Attenuation and half-value thicknesses for gamma and X-ray shielding materials

Shielding for neutrons

Designation of radiation areas

Radiation surveys – monitoring and record keeping.

Internal radiation hazards and protection measures:

Radioactive contamination (airborne, surface, liquid)

Routes of entry into human body

Exit routes and biological half-life

Dose-per-unit uptake for inhalation and ingestion

Control of contamination

Designation of contamination areas; typical barrier controls; administrative controls; house rules

Treatment of contaminated personnel

Contamination surveys – monitoring and record keeping.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply knowledge of the science of radiation to design, implement and measure the effectiveness of radiation protection controls		
P1 Discuss the nature and properties of radioactivity and radiation, including the interaction of radiation with matter, radiation units, biological effects of radiation exposure, natural and human-made radiation in the environment.	**M1** Solve numerical problems involving radioactive decay and estimation of radiation exposure.	**D1** Quantitatively analyse the efficacy of radiation protection measures using the science of radioactivity and radiation.
LO2 Interpret radiation protection legislation and formulate management advice on radiation protection strategies in accordance with the relevant approved code of practice		
P2 Interpret the basic requirements of radiation protection legislation and the relevant approved code(s) of practice.	**M2** Discuss the underlying rationale for requirements of radiation protection legislation and the relevant approved code(s) of practice.	**D2** Critically evaluate and interpret radiation protection legislation and formulate management advice on radiation protection strategies in accordance with the relevant approved code(s) of practice.

Pass	Merit	Distinction
LO3 Review radiation protection strategies in the workplace to ensure that radiation exposures are as low as reasonably practicable		
P3 Review the key elements of radiation monitoring and protection strategies in the workplace and carry out simple calculations related to radiation exposure.	**M3** Discuss the key elements of radiation protection strategies in the workplace and carry out optimisation studies to demonstrate that exposures are as low as reasonably practicable.	**D3** Critically review radiation protection strategies in the workplace, make recommendations to enhance radiation protection and support recommendations with quantitative analysis, including cost-benefit analysis.
LO4 Review the advice to relevant personnel on the effects of radiation exposure, radiation protection regulations and compliance procedures to personnel working in radiation environments.		
P4 Review the effects of radiation protection regulations and compliance procedures on personnel working in radiation environments.	**M4** Evaluate the current guidance given for personnel working in radiation environments on the effects of radiation exposure, radiation protection regulations and compliance procedures.	**D4** Critically analyse, by means of a presentation, the guidance for personnel working in radiation environments on the effects of radiation exposure, radiation protection regulations and compliance procedures.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Cember, H. and Johnson, T. E. (2009) *Introduction to Health Physics*. 4th Ed. New York: McGraw-Hill.

Martin, A. and Harbison, S. (2006) *An Introduction to Radiation Protection*. 5th Ed. London: Hodder Arnold.

Links

This unit links to the following related unit:

Unit 5040: Nuclear Safety Case Development.

Unit 5036: Nuclear Reactor Materials

Unit Code: **M/615/1543**

Level: **5**

Credits: **15**

Introduction

Understanding the fundamental material science and material changes in a nuclear reactor is central to the safe and efficient operation of a nuclear power plant. Past evidence has shown that failure to select the appropriate materials for key components and systems combined with failure to predict and control the changes in the material properties over time can result in expensive repairs, long periods of unproductive shut-down and, in the worst cases, unsafe plant conditions.

Materials science is important in all industrial activities. However, in the nuclear power industry, there are special considerations to be taken into account, such as the need to understand, predict and control the effect of radiation on material properties. Major components, such as the reactor pressure vessel, are subject to long-term, intense irradiation and this can lead to changes in properties such as ductility and embrittlement. These changes have an important impact on reactor operations – specifically on the temperature and pressure to which the vessel can be subjected. Therefore, the materials scientist on a nuclear power plant has an important operational role.

The purpose of this unit is to provide students with a clear understanding of the materials science underlying nuclear reactor design and operation, enabling them to describe, analyse, explain and calculate various changes and transitions that occur in the system over time. Topics included in this units are basic materials science (properties of materials, metals, alloys, phase diagrams and material processing), materials used in nuclear reactors (e.g. steels, zirconium) and changes that occurs in components due to various types of radiation (alpha, beta, gamma and neutron).

On successful completion of this unit students will be able to explain, measure and control materials and material changes relevant to a nuclear reactor and advise on materials science-related matters.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Illustrate the importance of atomic arrangement on mechanical properties of reactor core materials

LO2 Analyse mechanical and thermal properties and manufacturing techniques that are considered in the design and materials selection of PWR components

LO3 Analyse the changes in material properties that occur in PWR components as a result of radiation (α, β, γ and neutron) exposure

LO4 Discuss the use of zirconium and 20/25/Nb stainless steel in nuclear reactors.

Essential Content

LO1 Illustrate the importance of atomic arrangement on mechanical properties of reactor core materials

Materials science:

Electronic, atomic, micro and macrostructural arrangements and properties of metallic materials, mechanical properties, phase diagrams, material processing

Alloy definition and application, compressive strength, expansion/contraction associated with temperature changes, heat treating and annealing related to the properties of metals, radiation-induced embrittlement by neutron exposure, material strength, torque limits, yield and tensile strength

Brittle fraction characteristics, mechanisms and temperature effects.

LO2 Analyse mechanical and thermal properties and manufacturing techniques that are considered in the design and materials selection of PWR components

Materials used in a PWR primary circuit:

The different materials used in a PWR primary circuit; sensitisation; components and characteristics of stress corrosion cracking (SCC); corrosion pit formation

Irradiation-assisted SCC; the effect of cold work and corrosion potential on SCC; low-alloy steel for reactor pressure vessel; master curve approach to fit fracture data; fabrication process of a reactor pressure vessel; residual stress, primary stress and secondary stress; plastic collapse load; pellet-clad interactions in PWR and AGR systems; pellet cracking process; postulated clad damage models for AGR and PWR.

LO3 Analyse the changes in material properties that occur in PWR components as a result of radiation (α, β, γ and neutron) exposure

Neutron irradiation and embrittlement:

The process of neutron irradiation

Reactor pressure vessel lifetime

Irradiation-induced embrittlement

Alpha and beta irradiation

Gamma irradiation and its effect on the structural materials

Calculations related to radiation damage and neutron embrittlement.

LO4 **Discuss the use of zirconium and 20/25/Nb stainless steel in nuclear reactors.**

Zirconium in nuclear reactors:

Zr metallurgy, Zr phase diagram and Zr properties, Zr tube fabrication and fuel assembly manufacture

Defects in Zr

Hydrides and oxidation.

20/25/Nb stainless steel:

Mechanical and thermal properties, metallurgy, cladding fabrication, chemical behaviour.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Illustrate the importance of atomic arrangement on material properties of reactor core materials		
P1 Illustrate common crystal structures and various material properties relevant to reactor core materials.	**M1** Discuss how atomic arrangements impact material properties.	**D1** Evaluate the importance of atomic arrangement on physical, mechanical and thermal properties of reactor materials; provide supporting calculations related to the mechanical properties of materials.
LO2 Analyse mechanical and thermal properties and manufacturing techniques that are considered in the design and materials selection of PWR components		
P2 Analyse common practices for manufacturing PWR components and mechanical and thermal properties expected from those components.	**M2** Investigate the material properties relevant to nuclear reactors and compare manufacturing techniques for PWR component production.	**D2** Critically analyse the various material properties relevant to nuclear reactors and compare manufacturing techniques for PWR component production. Advise on material selection when designing and manufacturing reactor components.

Pass	Merit	Distinction
LO3 Analyse the changes in material properties that occur in PWR components as a result of radiation (α, β, γ and neutron) exposure		
P3 Analyse the changes in material properties that occur in PWR components due to various radiation exposures.	**M3** Carry out calculations related to radiation damage and embrittlement and, using these calculations, explain the changes in material properties that occur in PWR components due to radiation exposure.	**D3** Critically analyse how the changes in material properties occur in reactor components due to radiation exposure and advise on selecting materials that have the best overall behaviour in such environments.
LO4 Discuss the use of zirconium and 20/25/Nb stainless steel in nuclear reactors.		
P4 Discuss basic properties of zirconium and 20/25/Nb stainless steel and its use in the nuclear industry.	**M4** Discuss physical, mechanical and thermal properties of zirconium and 20/25/Nb stainless steel, and their use in the nuclear industry.	**D4** Critically examine the physical, mechanical and thermal properties of zirconium and its alloys, zirconium metallurgy and explain the use of zirconium in the nuclear industry. **D5** Critically examine the physical, mechanical and thermal properties of 20/25/Nb stainless steel and explain the use of this alloy in the nuclear industry.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Linga, K. and Murty, I. C. (2012) *An Introduction to Nuclear Materials: Fundamentals and Applications.* Boston: Wiley.

Nikjoo, H., Uehara, S. and Emfietzoglou, D. (2012) *Interaction of Radiation with Matter*. Boca Raton: CRC Press.

Was, G. S. (2007) *Fundamentals of Radiation Materials Science: Metals and Alloys.* New York: Springer.

Links

This unit links to the following related units:

Unit 5034: Nuclear Reactor Chemistry.

Unit 5037: Nuclear Fuel Cycle Technology

Unit Code: **T/615/1544**

Level: **5**

Credits: **15**

Introduction

The nuclear fuel cycle comprises the series of steps involved in the manufacture of nuclear reactor fuel from raw materials (usually uranium-bearing natural ores) and the series of steps involved in safely storing, processing and disposing of used fuel while effectively managing all wastes arising from the activity.

The UK is a world-leader in nuclear fuel cycle technology with advanced industrial facilities involved in uranium processing, conversion, enrichment, fuel manufacture, spent fuel storage, reprocessing, recycling and disposal. It is estimated that some 10,000 people work in nuclear fuel operations in the UK, mostly in scientific, engineering or technology-related disciplines. Major investments are planned in this sector to meet the fuel production and used-fuel management requirements for an expanding UK nuclear power programme.

The nuclear fuel cycle is important as it represents a significant contribution to the whole-life cost of operating a nuclear power programme. It is therefore important to understand the primary cost drivers to make rational decisions on the use of resources and optimise the search for efficiencies. An important example of this arises from the question of whether used nuclear fuel should be reprocessed and recycled (a 'closed' fuel cycle), or whether it is more cost-effective to dispose of spent fuel assemblies in an appropriate geological disposal facility (an 'open' fuel cycle). This question is of major importance to the future of the UK nuclear fuel industry.

Notwithstanding cost issues, the various steps involved in the nuclear fuel cycle have significant safety and environmental aspects and these must be clearly understood and rigorously controlled to meet stringent safety and environmental targets.

While today's nuclear fuel cycle is almost completely based on the utilisation of uranium in thermal reactors, a great deal of research is currently underway on alternative fuel cycles – for example, based on thorium – and on the development of fast reactors capable of using uranium and plutonium much more effectively than current plants. Hence, the nuclear fuel cycle is an area of active research and development.

The purpose of this unit is to provide a comprehensive overview of the nuclear fuel cycle, describing the technical, industrial, economic, safety and environmental issues involved at each step. The unit covers the entire fuel cycle – from the extraction of raw ore to the disposal of spent fuel and radioactive wastes. The unit focuses on the UK perspective; however, where appropriate, international and global issues will be highlighted.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Apply scientific fundamentals to describe the technological processes involved in each step of the nuclear fuel cycle and explain how the technology is applied on an industrial scale in the UK

LO2 Examine the safety and environmental issues arising at each step in the nuclear fuel cycle and explain how the associated challenges are being met

LO3 Undertake mass-flow and cost calculations over the entire fuel cycle, identify the key cost drivers and critically examine the financial case for nuclear fuel reprocessing

LO4 Review future developments in the nuclear fuel cycle, including the use of alternative nuclear fuel cycles, describe the associated technological challenges and critically assess the safety, environmental and financial benefits.

Essential Content

LO1 **Apply scientific fundamentals to describe the technological processes involved in each step of the nuclear fuel cycle and explain how the technology is applied on an industrial scale in the UK**

Nuclear fuel cycle (front-end processes):

Uranium exploration: mining and milling; uranium purification and conversion (wet and dry processes); advantages/disadvantages of underground, open-pit, in-situ leaching

Uranium enrichment: history, development, diffusion and centrifuge methods, laser-based methods, separation factor, calculations of feed-to-product mass ratio and separative work

Fuel manufacture: fuel types (metal alloy, oxide), reconversion to uranium oxide, pellet production; fuel pin manufacture; fuel assembly: examination; testing and quality assurance.

Nuclear fuel cycle (back-end processes):

Properties of spent fuel; at-reactor storage; cooling ponds; dry storage

Transportation of used fuel; flask design, testing; transport arrangements and regulations

Spent fuel reprocessing: history; current status; organic solvent extraction; PUREX process; centrifugal extraction; extraction and purification of uranium and plutonium

Recycling: recycling uranium; recycling plutonium as mixed-oxide (MOX) fuel

Waste management: vitrification of HLW; treatment and on-site storage of ILW; treatment and disposal of LLW; geological disposal facility (GDF): outline plan, timeline.

LO2 **Examine the safety and environmental issues arising at each step in the nuclear fuel cycle and explain how the associated challenges are being met**

Front-end processes:

Radiological safety issues in uranium mining; environmental protection in uranium mining and milling; hazards posed by HEX (UF_6) and key protective measures; safety and environmental protection during fuel fabrication.

Back-end processes:

Characteristics and radiological properties of spent fuel; hazards and protective measures during storage and transport; radiation protection and criticality control during reprocessing; hazards and protective measures for plutonium; radiological environmental impact assessment for discharges and disposals.

LO3 **Undertake mass-flow and cost calculations over the entire fuel cycle; identify the key cost drivers and critically examine the financial case for nuclear fuel reprocessing**

Uranium supply, demand and price:

Sources of information; factors affecting uranium supply, demand and price; global suppliers by country and corporation; uranium resources and future requirements; uranium spot price versus long-term contract prices; future outlook for uranium prices.

Enrichment and fabrication costs; recycling savings:

Enrichment costs: calculate optimum tails assay from feed and separative work costs; evaluate impact of changes to feed/separative work costs on tails assay; impact of worldwide enrichment capacity on price of enrichment services

Fuel manufacturing costs: cost drivers; impact of worldwide capacity for fuel manufacture on price of manufacturing services

Cost integration: mass-flow estimates; calculation of price of annual fuel requirement for a typical commercial reactor; price savings from uranium and plutonium recycling; economic case for reprocessing and recycling; price savings from use of military stockpiles

Estimate the saving in fuel costs from the use of recycled uranium and/or plutonium.

LO4 **Review future developments in the nuclear fuel cycle, including the use of alternative nuclear fuel cycles; describe the associated technological challenges and critically assess the safety, environmental and financial benefits.**

Thorium fuel cycle:

Physical, chemical and isotopic properties of natural thorium; abundance and extraction; conversion of thorium into fissile U-233; use of U-233 as a reactor fuel; key steps in a thorium-based nuclear fuel cycle.

Fast reactor fuel cycles:

Characteristics of fast reactors; typical fuel inventory; fast breeder reactors; impact of fast reactors on the overall utilisation of uranium; key steps in a fast reactor nuclear fuel cycle.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply scientific fundamentals to describe the technological processes involved in each step of the nuclear fuel cycle and explain how the technology is applied on an industrial scale in the UK		**D1** Undertake a critical review of current technology adopted at each stage in the nuclear fuel cycle and explain where improvements in technology can realise improvements in cost, safety and/or environmental impact.
P1 Apply scientific fundamentals to identify the physical and chemical form of uranium at each step in the fuel cycle. **P2** Describe the physical and chemical processes involved at each step in the fuel cycle.	**M1** Describe the processing steps involved at each stage in the nuclear fuel cycle and identify the challenges involved in adapting the processes for industrial-scale application and how these challenges have been met in the UK.	
LO2 Examine the safety and environmental issues arising at each step in the nuclear fuel cycle and explain how the associated challenges are being met		**D2** Quantitatively assess the hazards and risks at various stages of the nuclear fuel cycle and set the radiological hazards and risks in the wider context by comparing and contrasting with risks in other fuel-producing industries (oil, gas, etc.).
P3 Identify the main sources of radiation and radioactive discharges at each stage in the fuel cycle. **P4** Explain the main protective measures used to control radiation exposures to workers in fuel cycle facilities.	**M2** Estimate the magnitude of radiation exposures to workers and public at various stages of the fuel cycle. **M3** Estimate the magnitude, characteristics and radiological impact of radioactive discharges from the fuel cycle.	

Pass	Merit	Distinction
LO3 Undertake mass-flow and cost calculations over the entire fuel cycle, identify the key cost drivers and critically examine the financial case for nuclear fuel reprocessing		
P5 Calculate the cost of a reactor fuel load.	**M4** Calculate the savings from reprocessing and recycling on the costs of a fuel load.	**D3** Formulate a pricing model to compare the costs of closed versus open fuel cycle and critically assess the financial case for reprocessing and recycling now and in the future.
LO4 Review of future developments in the nuclear fuel cycle, including the use of alternative nuclear fuel cycles, describe the associated technological challenges and critically assess the safety, environmental and financial benefits.		
P6 Review the key steps in nuclear fuel cycles based on thorium and fast reactors.	**M5** Discuss the technological challenges involved in the development of thorium and fast reactor fuel cycles.	**D4** Critically assess the outlook for thorium-based and fast reactor fuel cycles in the context of international development of Generation IV Nuclear Power Systems.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Cochran, R. G. (1999) *The Nuclear Fuel Cycle: Analysis and Management*. Washington, DC: American Nuclear Society.

Knief, R. A. (1992) *Nuclear Engineering*. Carlsbad: Hemisphere.

Wilson, P. D. (1996) *The Nuclear Fuel Cycle*. Oxford: Oxford University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

NEA/OECD Publication, *Uranium Resources, Production and Demand* ('The Red Book'), published annually.

Websites

http://www.world-nuclear.org/	World Nuclear Association

Unit 5038: Nuclear Decommissioning and Radioactive Waste Management Technologies

Unit Code: A/615/1545

Level: 5

Credits: 15

Introduction

The UK has operated nuclear power reactors since the 1950s. The first generation of commercial nuclear power stations based on Magnox reactors are now shut down after more than 40 years of operation. These power stations are now undergoing decommissioning. In the next 10–15 years, the second generation of power stations based on Advanced Gas-Cooled Reactors will reach the end of their working life and will also begin the process of decommissioning. It is estimated that more than 1000 people currently work in the nuclear decommissioning sector – a number which is expected to grow considerably as the number of plants undergoing decommissioning increases.

The decommissioning of nuclear power plants requires specialist knowledge, skills and expertise. This is because nuclear decommissioning involves radioactive materials of various kinds. Radiation safety of both workers and the public is therefore of primary concern. Consequently, many new methods have been developed especially for nuclear decommissioning – usually involving robotics or other remote handling solutions. Some contaminated items, such as concrete, require special decontamination techniques to be applied to reduce the volume of radioactive wastes.

At each stage of nuclear decommissioning – from the removal of the last fuel load to the final removal of all buildings from the site – radioactive wastes need to be collected, conditioned, stabilised and prepared for long-term, safe disposal. Higher activity wastes will eventually be stored long term in an underground geological disposal facility (GDF). The entire process is monitored closely by the nuclear safety and environmental regulatory bodies.

The aims of this unit are to provide students with an understanding of the technologies associated with nuclear decommissioning and radioactive waste management. The regulatory framework for decommissioning and waste management is described, including regulatory criteria and guidance on the required end-state of decontamination and clean-up processes.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate a range of specialist technologies developed for nuclear decommissioning and radioactive waste immobilisation

LO2 Review the management of decommissioning, the deployment of technological solutions and the process of hazard reduction, using case studies

LO3 Discuss the regulatory framework governing the safety and environmental impacts of nuclear decommissioning and radioactive waste management

LO4 Evaluate current arrangements and future plans for radioactive waste disposal in the UK and critically assess strategic and technological bases for the plans.

Essential Content

LO1 **Evaluate a range of specialist technologies developed for nuclear decommissioning and radioactive waste immobilisation**

Decontamination techniques:

Non-attritive cleaning; chemical decontamination techniques; physical attrition techniques.

Dismantling techniques:

Mechanical cutting techniques; thermal cutting techniques; other methods.

Remote handling techniques:

Use of robotics in nuclear decommissioning.

Radiation protection techniques:

Contamination control; use of Personal Protective Equipment; abatement technologies for liquid and gaseous radioactive discharges; technologies for immobilisation of radioactive waste.

LO2 **Review the management of decommissioning, the deployment of technological solutions and the process of hazard reduction, using case studies**

Decommissioning project management:

Key drivers influencing decommissioning plans and programmes; hazard reduction (including hazard and risk); planning framework for nuclear decommissioning; project management principles, planning, control and monitoring; project prioritisation; social and political issues; stakeholder engagement.

Decommissioning case studies – learning from experience:

Decommissioning experience of: Windscale Piles; Windscale Advanced Gas Reactor (WAGR); JASON at Royal Naval College; CONSORT reactor at Imperial College; US experience.

LO3 **Discuss the regulatory framework governing the safety and environmental impacts of nuclear decommissioning and radioactive waste management**

Licensing prerequisites associated with decommissioning:

Funded Decommissioning Programme

Designing for decommissioning.

Regulatory oversight of nuclear safety aspects of decommissioning:

Role of ONR; nuclear site licence conditions; delicensing criteria; clean-up and remediation of contaminated land; site restoration issues.

Regulatory oversight of environmental impact of decommissioning:

Role of Environment Agencies; Environmental Impact Assessment of Decommissioning Regulations – requirements; Environmental Permitting Regulations; Regulation of radioactive discharges; Regulation of radioactive waste disposals; impact of international obligations on discharge limits.

LO4 **Evaluate current arrangements and future plans for radioactive waste disposal in the UK and critically assess strategic and technological bases for the plans.**

Key stakeholders:

Role of UK Nuclear Decommissioning Authority (NDA) in radioactive waste management; NDA strategy for radioactive waste management; role of the Committee on Radioactive Waste Management (CoRWM).

Current arrangements for radioactive waste disposal:

Waste classifications and implications on waste treatment methodologies; radioactive waste classification scheme; definition of HLW, ILW, LLW and VLLW; origin, physical/chemical form and inventory of radioactive waste; disposal of LLW; sources, volumes, activities and characterisation of LLW; arrangements for the disposal of LLW at the LLWR, Drigg; technological, safety and environmental aspects of LLW disposal; current arrangements for conditioning and storage of ILW and HLW; characterisation, processing, immobilisation, packaging, transport and storage of ILW; current arrangements for conditioning and storage of HLW; origins, disposition, physical and chemical form, storage arrangements for HLW.

Plans for a geological disposal facility (GDF):

Lead agency and stakeholders in the GDF project; outline plans and timescales; key design features; physical barriers; GDF safety case issues – potential hazards and protective measures; environmental case and impact assessment; HLW disposal arrangements in other countries – current status.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate a range of specialist technologies developed for nuclear decommissioning and radioactive waste immobilisation		
P1 Evaluate the main techniques used in nuclear decommissioning. **P2** Evaluate the main techniques used for radioactive waste immobilisation.	**M1** Compare the efficacy of given techniques used in nuclear decommissioning. **M2** Compare given techniques used for radioactive waste immobilisation and assess each technique on the basis of efficacy and value-for-money.	**D1** Review research activities aimed at developing improved techniques and critically assess techniques used in nuclear decommissioning, identifying areas for improvement.
LO2 Review the management of decommissioning, the deployment of technological solutions and the process of hazard reduction, using case studies		
P3 Review the decommissioning techniques used in a particular decommissioning project.	**M3** Assess the application of technology to decommissioning in a particular project and summarise the key lessons learned.	**D2** Critically assess the overall management arrangements for a case study in decommissioning; identify the key lessons learned from both a project management and technology application perspective and make recommendations for improvement.

Pass	Merit	Distinction
LO3 Discuss the regulatory framework governing the safety and environmental impacts of nuclear decommissioning and radioactive waste management		
P4 Discuss the principles of safety and environmental regulation of nuclear decommissioning projects.	**M4** Assess the regulatory arrangements for safety and environmental protection in decommissioning projects.	**D3** Critically examine the impact of regulatory requirements on the project, using case studies; assess the impact of regulation on safety and environmental outcomes and consider the cost implications of meeting regulatory targets.
LO4 Evaluate current arrangements and future plans for radioactive waste disposal in the UK and critically assess strategic and technological bases for the plans.		
P5 Evaluate arrangements for LLW disposal in the UK and outline plans for a GDF.	**M5** Investigate the arrangements for LLW disposal in the UK and outline plans for a GDF and, for each, examine the safety and long-term environmental issues considered in the safety and environmental analyses.	**D4** Critically evaluate the wider safety, environmental and socio-economic issues associated with the development and siting of facilities for LLW disposal and the GDF for ILW and HLW.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bayliss, C. and Langley, K. (2003) *Nuclear Decommissioning, Waste Disposal and Environmental Site Remediation.* London: Butterworth-Heinemann.

Links

This unit links to the following related units:

Unit 5033: Nuclear Reactor Operations

Unit 5034: Nuclear Reactor Chemistry

Unit 5036: Nuclear Reactor Materials.

Unit 5039: Nuclear Criticality Control

Unit Code: **F/615/1546**

Level: **5**

Credits: **15**

Introduction

Nuclear reactors use fissile material to create a controlled neutron-induced fission chain reaction. This means that fissile material is present throughout the nuclear fuel cycle.

A criticality accident is defined as an unplanned, criticality excursion involving fissile material not inside a nuclear reactor. Criticality accidents can give rise to an explosive release of energy and intense radiation. Previous criticality accidents in the US, Russia and Japan have resulted in casualties. Over 100 criticality accidents have been recorded and reported throughout the world; of these, the overwhelming majority have taken place in facilities where highly fissile material (enriched uranium or plutonium) was undergoing chemical processing in the form of a solution. Clearly, then, criticality controls where fissile material is present in liquid form must be particularly stringent and require rigorous adherence.

The avoidance of unplanned criticality is usually referred to as criticality control or criticality safety management. Methods of control are based on engineering design, operational limits and administrative practices. The purpose of criticality safety by design is to ensure that all vessels that could potentially contain fissile material have a material composition and geometrical shape that renders criticality physically impossible. In addition, where the fissile material is present as an array of units, the physical separation and spacing materials should be designed to make criticality impossible.

This unit provides a comprehensive introduction to nuclear criticality safety in facilities, or situations where fissile materials are encountered outside a nuclear reactor. The unit, which reflects the core competencies specified by the United Kingdom Working Party on Criticality (WPC), focuses on criticality assessments and safety by design; however, with reference to previous criticality accidents, the importance of operational limits, human error and safety management arrangements is also highlighted.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Produce a comprehensive criticality safety assessment of an operational or (hypothetical) nuclear facility involved in the use, storage or processing of fissile materials, applying a range of techniques, including both analytical and computational methods

LO2 Investigate the appropriate regulatory legislation, guidance and industry standards to criticality assessments, justifying their analysis through the appropriate use of data, benchmarks, cross-comparison of methods, and/or sensitivity analysis

LO3 Investigate how facilities can be designed and operated to reduce the likelihood and/or consequences of an unplanned criticality excursion

LO4 Examine previous recorded criticality accidents, analyse the root causes and draw conclusions on lessons to be learned.

Essential Content

LO1 **Produce a comprehensive criticality safety assessment of an operational or (hypothetical) nuclear facility involved in the use, storage or processing of fissile materials, applying a range of techniques, including both analytical and computational methods**

Physics aspects of criticality:

Review of nuclear fission; fission with fast and thermal neutrons; neutron moderation; moderator effectiveness; neutron life cycle; neutron lifetime, neutron multiplication factor

Definition of reactivity; reactivity units; fast fission, fast leakage, resonance absorption, thermal leakage, fuel utilisation, thermal reproduction; derivation of six-factor formula; reactivity calculations based on six-factor formula; prompt and delayed neutrons; significance of delayed neutrons in criticality control; response to reactivity addition without and with delayed neutrons; neutron doubling time, start-up-rate; consequences of excessive reactivity addition.

Criticality assessments (reactivity calculations):

Hand methods using six-factor formula: buckling/shape conversion method; surface density method for fissile arrays; density analogue and solid angle methods; limitations and uncertainties in hand calculations

Computer modelling for criticality safety: overview of transport theory; overview of Monte-Carlo approach; verification and validation of computer codes; limitations and uncertainties in computer-based codes.

LO2 **Investigate the appropriate regulatory legislation, guidance and industry standards to criticality assessments, justifying their analysis through the appropriate use of data, benchmarks, cross-comparison of methods, and/or sensitivity analysis**

UK regulatory requirements for criticality safety:

Criticality control addressed in nuclear site licence conditions; criticality control addressed in ONR safety assessment principles; ONR Technical Assessment Guide for Criticality Control – key requirements

Criticality standards: sub-criticality limits; single and multi-parameter limits; operating limits (single units and arrays).

LO3 **Investigate how facilities can be designed and operated to reduce the likelihood and/or consequences of an unplanned criticality excursion**

Methods and practices for criticality control:

Administrative controls; operational controls; geometry, poisons, mass/volume limits, moderation and concentration; reflectors; criticality hazards and control measures in practice: fuel manufacture, decommissioning; spent fuel reprocessing, spent fuel storage and transport.

LO4 **Examine previous recorded criticality accidents, analyse the root causes and draw conclusions on lessons to be learned.**

Criticality incidents and accidents:

Y-12 Plant; LASL, ICPP, Wood River Plant, Tokaimura (Japan); accident sequence and consequences; general observations; root causes: design, system failures, human error, safety management shortcomings, regulatory shortcomings.

Criticality incident detection:

Prompt and delayed radiation from criticality; criticality assessment by neutron flux measurement; criticality assessment using neutron activation; criticality lockets.

Criticality accident response arrangements:

Review of facility emergency procedures for criticality accidents.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Produce a comprehensive criticality safety assessment of an operational or (hypothetical) nuclear facility involved in the use, storage or processing of fissile materials, applying a range of techniques, including both analytical and computational methods		
P1 Produce a hand-calculation (not using a computer model) criticality assessment for a fissile unit with simple geometry.	**M1**Produce a hand-calculation criticality assessment for an array of fissile units with complex geometry.	**D1** Quantify the limitations of both hand and computer-based calculations and make recommendations on how the criticality assessment analysis could be improved.
LO2 Investigate the appropriate regulatory legislation, guidance and industry standards to criticality assessments, justifying their analysis through the appropriate use of data, benchmarks, cross-comparison of methods, and/or sensitivity analysis		
P2 Investigate the underlying regulatory requirements pertaining to criticality control.	**M2** Assess both regulatory and industry standards for criticality control.	**D2** Critically evaluate the regulatory approaches and industry standards used for criticality control in a specified number of countries, including the UK and USA.

Pass	Merit	Distinction
LO3 Investigate how facilities can be designed and operated to reduce the likelihood and/or consequences of an unplanned criticality excursion		
P3 Investigate how design criteria can reduce the likelihood of unplanned criticality.	**M3** Show how design and operational aspects contribute to the overall control of criticality risk.	**D3** Critically evaluate the design, operational, administrative and safety management arrangements for criticality control at a real nuclear facility.
LO4 Examine previous recorded criticality accidents, analyse the root causes and draw conclusions on lessons to be learned.		
P4 Examine the primary causes of criticality accidents.	**M4** Evaluate a range of criticality accidents and formulate conclusions on common root causes and lessons to be learned.	**D4** Undertake an analysis of a criticality accident (e.g. Tokaimura); consider the radiological and wider socio-economic consequences of the accident and investigate the contributory factors and underlying root causes.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Knief, R. A. (1985) *Nuclear Criticality Safety: Theory and Practice*. La Grange Park: American Nuclear Society.

Websites

http://www.nuclearinst.com/	Nuclear Institute Working Party on Criticality (General reference)

Links

This unit links to the following related units:

Unit 5035: Nuclear Radiation Protection Technology

Unit 5040: Nuclear Safety Case Development.

Unit 5040: Nuclear Safety Case Development

Unit Code: J/615/1547

Level: 5

Credits: 15

Introduction

The development and implementation of a nuclear safety case is an essential requirement for the achievement and maintenance of a licence to construct, operate and decommission a nuclear facility.

The Nuclear Installations Act (1965(9)) requires that any organisation wishing to construct and operate a nuclear plant must first obtain a licence from the relevant regulatory body, currently the Office for Nuclear Regulation (ONR). The nuclear site licence is only granted following the submission of a comprehensive, auditable nuclear safety case demonstrating that acceptable levels of safety have been achieved in design and operation. The nuclear safety case is defined as *a documented body of **evidence** that provides a convincing and valid **argument** that a nuclear system, process or plant is **adequately safe** for a given application in a given environment.*

Previous experience of both nuclear and non-nuclear accidents has reinforced the requirement for safety cases. More exactly, experience has highlighted the need to *act on the recommendations* of the safety case and to establish safety management arrangements which ensure a plant is *operated within the scope of the safety case*.

Safety case development has evolved into a discipline in its own right within the nuclear industry. Consequently, many jobs within the industry are described in terms such as ‘Safety Case Manager’, ‘Safety Analyst’ or ‘Safety Case Engineer’. In addition to these specialist functions, most nuclear safety cases are multidisciplinary and require inputs from a wide range of specialists including mechanical, electrical and civil engineers, radiological experts and even psychologists. Also, nuclear safety cases rely on input from experienced workers on the plant under consideration. Consequently, many people working in the nuclear industry will contribute to safety case development at some point in their career.

The aim of this unit is to provide students with the underpinning knowledge and experience required to contribute effectively to the development of a nuclear safety case, applying best practice and meeting all regulatory expectations. A secondary aim of the unit is to provide students with an appreciation of the role of the safety case in the safety management arrangements for the facility and the need to work within the boundaries of the safety case at all times.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Discuss the purpose, scope and content of a nuclear safety case and apply regulatory requirements, expectations and guidance in the development of a safety case to modern standards

LO2 Apply structured techniques for the identification and analysis of hazards, the analysis of fault sequences and their potential radiological consequences and the quantification of risk

LO3 Undertake analyses of routine operations and fault conditions, including design basis analysis (DBA) and probabilistic safety analysis (PSA), as part of a structured safety analysis for a nuclear facility

LO4 Illustrate how the nuclear safety case supports the wider nuclear safety management arrangements at a nuclear facility and appreciate the importance of working within the boundaries of the safety case.

Essential Content

LO1 **Discuss the purpose, scope and content of a nuclear safety case and apply regulatory requirements, expectations and guidance in the development of a safety case to modern standards**

Regulatory expectations and guidance on nuclear safety cases:

Requirements of UK H&S legislation; Nuclear Site Licence Conditions (LCs); LCs 14, 15, 19 and 22

Regulatory guidance nuclear safety cases; relevant Safety Assessment Principles and Technical Assessment Guides (TAGs); regulatory assessment of nuclear safety cases; key engineering principles; categorisation of safety functions; classification of safety systems; use of redundancy, diversity, segregation; single failure criterion and defence in depth.

Constructing the safety case:

Use of claim, evidence, argument; assumptions and conditions on claims; deterministic, probabilistic and qualitative arguments; structured approach; layered safety cases.

Risk concepts and the use of risk in safety cases:

Definition of risk as frequency x consequence; consequence metrics in nuclear safety cases; risk plots and targets; individual risk and societal risk; numerical limits and targets for risk; Basic Safety Limit (BSL); Basic Safety Objective (BSO).

LO2 **Apply structured techniques for the identification and analysis of hazards, the analysis of fault sequences and their potential radiological consequences and the quantification of risk**

Hazard identification and analysis techniques:

Application of hazard identification techniques including structured checklists, engineering walk-down, HAZOPS, HAZANS, Failure Modes & Effects Analysis (FMEA); use of hazard analysis to identify initiating events for fault sequence analysis.

Introduction to fault and event tree analysis (FETA):

Basic laws of probability; application of probability theory in reliability engineering; fault sequence modelling and evaluation using FETA; application of FETA to simple systems; single failure and common mode failure; minimal cut sets.

Introduction to human reliability analysis (HRA):

Use of HRA in risk assessment; application of HRA techniques: THERP, CBDT, HCR, ATHEANA; categories of human failures; HRA evidence gathering.

LO3 **Undertake analyses of routine operations and fault conditions, including design basis analysis (DBA) and probabilistic safety analysis (PSA), as part of a structured safety analysis for a nuclear facility**

Nuclear safety case for normal operations:

Calculations of on- and off-site radiation doses from routine operations; comparisons with BSL/BSO; application of ALARP; use of cost-benefit analysis (CBA) in ALARP judgements.

Nuclear safety case for fault conditions:

Purpose of design basis analysis (DBA); application of DBA to simple systems; fault sequence analysis; estimation of initiating event frequency and unmitigated dose; comparison with BSL/BSO targets; determination of reliability/effectiveness targets for safety systems; design substantiation

Purpose of probabilistic safety assessment (PSA); key steps and endpoints in Level 1, 2 and 3 PSA calculations; application of PSA to simple systems; comparison of PSA results with BSL/BSO targets; application of ALARP and CBA in PSA; strengths and weaknesses of PSA; use of sensitivity analysis to evaluate impact of uncertainties.

LO4 **Illustrate how the nuclear safety case supports the wider nuclear safety management arrangements at a nuclear facility and appreciate the importance of working within the boundaries of the safety case.**

Managing the production and maintenance of a nuclear safety case:

Safety cases over the plant life cycle; preliminary safety report (PSR); pre-construction safety report (PCSR); pre-commissioning safety report (PCmSR); pre-operational safety report (POSR); periodic safety review; project management plan (PMP) for safety case production; peer review, independent assessment and regulatory assessment of safety cases; attributes of good safety cases; common shortcomings and error traps; learning from experience: case studies on nuclear and conventional safety cases.

Safety case and operations:

Linkage between the safety case and plant operating rules; limits, procedures.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss the purpose, scope and content of a nuclear safety case and apply regulatory requirements, expectations and guidance in the development of a safety case to modern standards		
P1 Discuss the structure of a safety case report, describe the analysis requirements and specify appropriate safety limits and targets.	**M1** Explore the various purposes of a nuclear safety case and explain the rationale underlying the relevant safety limits and targets.	**D1** Critically review examples of safety cases, identify common shortcomings and cite examples of best practice.
LO2 Apply structured techniques for the identification and analysis of hazards, the analysis of fault sequences and their potential radiological consequences, and the quantification of risk		
P2 Apply basic-level fault and event tree analysis to independent safety systems.	**M2** Apply fault and event tree analysis to more complex systems with dependencies, common mode and common cause failures.	**D2** Apply 'industry-standard' fault and event tree software applications to a nuclear facility, describe its limitations and recommend areas for further development.

Pass	Merit	Distinction
LO3 Undertake analyses of routine operations and fault conditions, including design basis analysis (DBA) and probabilistic safety analysis (PSA), as part of a structured safety analysis for a nuclear facility		
P3 Undertake a safety analysis of a nuclear facility 'as built' and compare the results with relevant targets and limits.	**M3** Use the safety analysis for the 'as built' facility as the starting point for an ALARP assessment for a safety enhancement proposal.	**D3** Produce a comprehensive safety analysis of routine operations and fault conditions on a given nuclear plant, applying CBA methods as part of an ALARP assessment for a range of safety enhancement options.
LO4 Illustrate how the nuclear safety case supports the wider nuclear safety management arrangements at a nuclear facility and appreciate the importance of working within the boundaries of the safety case.		
P4 Illustrate a safety case for a simple system in terms of claim, argument and evidence.	**M4** Use the safety case to define operating rules, limits and procedures explaining the underlying rationale.	**D4** Construct a multi-layered safety case in terms of claim, argument and evidence and explicitly link the safety case to plant operating limits.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Fullwood, R. R. and HALL, R. E. (1988) *Probabilistic Risk Assessment in the Nuclear Power Industry: Fundamentals and Applications*. 1st Ed. Oxford: Pergamon Press.

Websites

http://www.onr.org.uk/	Office for Nuclear Regulation (General reference)

Links

This unit links to the following related units:

Unit 5035: Nuclear Radiation Protection Technology

Unit 5039: Nuclear Criticality Control.

Unit 5041: Engineering Project

Unit Code: **M/650/2948**

Level: **5**

Credits: **15**

Introduction

The work of the professional engineer very often consists of the specification, development, management and delivery of projects. It is essential that students following the path of becoming a professional engineer have a thorough grounding in all aspects of this important process.

This unit will guide the student through the design, testing and evaluation of a project within their specialist area. The processes of documenting, managing and presenting the outcomes of the project will form part of the work, as will the selection and use of commercially available management, simulation and presentation development tools.

Risk assessment, quality and cost issues, final analysis of outcomes, and the drawing of appropriate conclusions will also be covered. A final presentation will develop communication skills and include personal evaluation and reflection.

On successful completion of this unit, the student will have the skills and knowledge to initiate, manage, complete and evaluate complex engineering projects on-time and within budget.

Note to centre: This is essentially a practical unit with the completed project and all the attendant processes forming the assessed work; it is not expected that further work for assessment will be necessary. The Project Supervisor should guide students to ensure that the chosen project has enough scope to be sufficiently complex, such that the outcomes are at Level 5.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Propose an engineering-based project in line with national and international engineering regulatory and ethical frameworks

LO2 Create an engineering-based project using project management software, tools and techniques

LO3 Implement a project plan to include the production of a technical engineering report

LO4 Present the engineering-based project and reflect on the project outcomes.

Essential Content

LO1 **Propose an engineering-based project in line with national and international engineering regulatory and ethical frameworks**

Selection of a suitable project:

Shortlisting of suitable projects based on considerations of cost, likely completion constraints and user needs

Identification of the nature of the problems under consideration through primary and secondary research methods, using digital and non-digital sources and relevant technical, engineering, industry, regulatory, legislative and ethical standards and risk factors

Feasibility study to identify constraints; scoping by defining objectives, purpose and deliverables; production of outline briefs; Feasibility study to identify constraints; scoping by defining objectives, purpose and deliverables; production of outline briefs; consideration of project related responsibilities at various levels including secure operations and application of appropriate processes, policies and legislation in the context of business goals, vision and values; tools/techniques for upgrading and maintaining systems within the project scope; resilience in undertaking project tasks and work securely within the business.

Health and safety policies, procedures and regulations, compliance, risk assessment processes and procedures.

Selection criteria and process:

Development of selection criteria (e.g. time constraints, risk evaluation, cost, skills set, availability of materials, meeting the user needs)

Selection and justification process – final selection.

Project aims:

Description of engineering-based project intentions and achievements, (e.g. design, test, construct, replicate, question existing)

Refinement of aims to clearly define the purpose of the engineering-based project

Development of specific aims that are clear, concise and provide a logical flow between each aim to establish an engineering-based project as a coherent whole.

Project objectives:

Goals or steps to achieve engineering-based project aims (e.g. specific, measurable, achievable, realistic, time-constrained (SMART)).

Difference between project aims and objectives:

Aims – describe what is hoped to be achieved

Objectives – detail how project aims are to be achieved.

Project proposal development:

Outline/summary of project (e.g. the problem the project intends to solve, the solution the project provides to the problem, the impact the project will have)

Project background (e.g. what is already known about the problem, primary and secondary research undertaken/literature review)

Project approach (e.g. project schedule (including important milestones), project team roles and responsibilities, risk mitigation, project deliverables, reporting tools)

Defining project deliverables (e.g. end product or final objective, project timeline, SMART goals that align with deliverables)

Resources (e.g. budget, cost breakdown, resource allocation plan)

Conclusion (e.g. summary of problem and solution, project impact).

LO2 **Create an engineering-based project using project management software, tools and techniques**

Project management software, tools, methodologies and techniques:

Review commercially available project management tools/software to select most suitable; consideration of requirements of the chosen project, difference between systems (e.g. Prince 2) and software (e.g. PMIS, Microsoft Project, PROMIST); task and tracking tools and techniques (e.g. Trello, Smartsheet, Excel); scheduling and time planning (Gantt chart or similar); network diagrams, types and applications; critical-path methods (PERT); budget management tools

Methodologies (e.g. waterfall, Agile, Scrum, Kanban, Scrumban, eXtreme programming (XP), Adaptive Project Framework (APF), Lean)

Project management techniques (e.g. SWOT, stakeholder matrices, risk mapping, radar chart and summary risk profiles).

Selection and application:

Justification of selection by criteria, level of detail and usability, flexibility considerations and constraints; pre-population of planning tools and updating regime; evaluation and summary of usability on project completion.

Production of project plan:

Production of final project plan with clear lifecycle considerations (e.g. initiation, planning, execution, closure, review and reflection), roles and responsibilities, timeline goals (using Gantt chart or similar), budget management (if applicable), project evaluation criteria (e.g. decision matrix, Health, Environment & Safety (HES) decision matrix, analytic hierarchy process (AHP), cost-effectiveness, organisation-based information architecture (OBIA), meeting the user needs)

Key performance indicators (KPIs)

Other project planning and management considerations: change management, compliance in delivering outputs, responsible planning and work prioritisation, focus on products/processes that are accessible, inclusive and diverse; predictive maintenance, route-cause analysis and effective problem solving, individual and team approaches to solving problems and risk management); commitment to upskilling/reskilling (e.g. digital competencies, sustainability), and continued professional development.

LO3 **Implement the project plan to include the production of a technical engineering report**

Project execution phase:

Conduct or simulate planned project activities to generate outcomes which provide a solution to the identified engineering problem

Review a range of practical examples to solve potential structural or performance-based issues using simulation software or experimental approaches

Continuous monitoring of project development against agreed project plan, adapting plan where necessary – specification and justification of changes

Effective use of work plan and time management using chosen packages; assessing effectiveness and useability of monitoring package(s); tracking costs and timescales for spending; modification of risk assessment as project progresses

Maintaining a project diary to monitor progress against milestones and timescales, including self-reflection on skills and personal development.

Project report:

Possible report formats, logical presentation of work, use of evaluation techniques, critique of data/findings/analysis, presentation of final outcome in terms of original project brief, explanation of cost/time overruns; avoidance of generalisations

Drafting and reviewing work; adherence to international, national, Engineering Council and ethical standards

Recommendations for further work, limitations of chosen process, possible areas for improvement; reflection on process, selected software/process effectiveness; personal reflection – strengths and areas for development to attain sustainable high-performance levels.

Termination of project:

Cost performance analysis, audit tails, comparison of project outcomes against planned objectives, qualitative and quantitative analysis of process and outcomes; close-out reports

Preparation of data and analysis for summary presentation

Process of self-reflection on project and personal performance.

LO4 **Present the engineering-based project and reflection of the project outcomes.**

Presentation:

Selection of presentation format, audience expectations and contributions, who to invite; what to include in presentation, logical presentation, avoiding 'busy' slides and assumptions, time allocation, summaries and project evaluation, handling question and answer (Q&A) sessions; inclusion of reflective practice.

Reflective practice:

Reflection on the activities and experiences (e.g. lessons learnt, teamwork, safety awareness, self-organisation, managing people, sustainability, technical expertise, communication skills, challenges, difficulties, strengths/weaknesses, own work practices, identification of areas to improve)

Tools (e.g. strengths/weaknesses/opportunities/threats (SWOT) analysis, 5R (reporting, responding, relating, reasoning & reconstructing) framework for reflection, Kolb's reflective cycle, Driscoll's model of reflection, Gibbs' reflective cycle, Schon).

Feedback:

Noting audience/third-party feedback and action plan to address issues; completion and closure of project reflective log; refining future professional practice and building further resilience within the project teams.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Propose an engineering-based project in line with national and international engineering regulatory and ethical frameworks		
P1 Propose an engineering-based project brief in line with national and international engineering regulatory and ethical frameworks **P2** Develop engineering-based project proposal aims and objectives.	**M1** Undertake a feasibility study to justify engineering-based project proposal.	**D1** Illustrate the effects of relevant current legislation, ethics and risk in developing an engineering-based project proposal.
LO2 Create an engineering-based project using project management software, tools and techniques		
P3 Create a project plan using project management software, tools and techniques.	**M2** Make full use of project management software to develop a comprehensive project plan.	**D2** Make full use of project management software to develop a comprehensive project plan with evaluation criteria.

Pass	Merit	Distinction
LO3 Implement the project plan to include the production of a technical engineering report		
P4 Implement required project activities, recording progress against original project plan. **P5** Produce a coherent technical engineering project report covering each stage of the project. **P6** Conduct or simulate planned project activities to generate outcomes which provide a solution to the identified engineering problem.	**M3** Implement a full range of project activities, recording progress against original project plan. **M4** Produce a structured and detailed technical engineering project report covering each stage of the project that includes justified project outcomes. **M5** Review a range of practical examples to solve potential structural or performance-based issues using simulation software or experimental approaches.	**D3** Critically analyse the project outcomes in the project report against the original project plan, making justified recommendations for further improvements.
LO4 Present the engineering-based project and reflection of the project outcomes.		
P7 Present the engineering-based project using appropriate media to a technically literate audience, and conduct a feedback session. **P8** Reflect on project outcomes.	**M6** Evaluate the end-to-end delivery of the engineering-based project in terms of own performance and how third-party feedback might be addressed.	**D4** Critically evaluate the end-to-end delivery of the engineering-based project in terms of reflective practice and produce an action plan and recommendations for how third-party feedback might be addressed.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Blokdyk G. (2022) Engineering Project Manager Critical Questions Skills Assessment (Paperback).

Desai A. (2022) Engineering Project Management: A Quantitative Approach (Paperback). Cognella, Inc.

Malheiro B. and Fuentes-Durá P. (Editors) (2022) Analyzing the European Project Semester to Improve Engineering Education − e-Book Collection. IGI Global.

Ma Y. and Rong Y. (2021) Senior Design Projects in Mechanical Engineering: A Guidebook for Teaching and Learning (Hardback). Springer Nature Switzerland AG.

Newton R. (2016) *Project Management Step by Step*. 2nd Ed. Pearson Education.

Siegel N.G. (2019) *Engineering Project Management.* Wiley.

Striebig B., Ogundipe A. and papadakis M. (2015) *Engineering Applications in Sustainable Design and Development* (S.I. Edition). Cengage Learning.

Oberlender G.D. (2014) *Project Management for Engineering and Construction*. 3rd Ed. McGraw-Hill Education.

Qiu M., Qiu H., and Zeng Y. (2022) *Research and Technical Writing for Science and Engineering*. CRC Press.

Thiel D.V. (2014) *Research Methods for Engineers.* Cambridge University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

American Journal of Engineering Research

Arabian Journal for Science & Engineering

Scientific Reports

Engineering Reports

Science Progress

Cell Reports Physical Science

Engineering Research Express

European Journal of Engineering and Technology Research

IETE journal of research

Indian Journal of Engineering

International Journal of Indian Research

International Journal of Engineering Research in Africa

International Journal of Engineering Research & Technology

International Journal of Project Management

Journal of Engineering in Industrial Research

Journal of Engineering Research

Journal of Engineering Research and Sciences (JENRS)

Journal of Engineering Research and Reports

London Journal of Engineering Research

The Journal of Engineering Research [TJER].

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4031: Introduction to Professional Engineering Management

Unit 4062: Professional Engineering Practice

Unit 5001: Research Project

Unit 5002: Professional Engineering Management.

Unit 5042: Signals and Systems

Unit Code: **M/650/2984**

Level: **5**

Credits: **15**

Introduction

Signals and systems are extensively used in scientific, technological and engineering fields such as electrical circuits, communications, energy generation and distribution systems, chemical process control and speech processing. Whilst the nature of the signals and systems may vary for each application, they operate fundamentally on the same basic principles. Signals are functional representations of one or more independent variables that contain information about the behaviour of a physical quantity. Systems may respond to certain signals by producing other signals or some desired behaviour. In electrical circuits, voltages and currents are examples of signals, and the electrical circuit is an example of a system, which responds to applied voltages and currents to produce a desired output response.

The aim of this unit is to provide students with the fundamental knowledge of signals and systems by studying the behaviour of continuous-time and discrete-time signals and their applications in engineering systems. Students will use Fourier, Laplace and Z-transforms to analyse signals and systems in order to make an informed assessment of the accuracy of the transmitted information.

On successful completion of this unit, students will have developed the key knowledge of the operation and application of signals and systems within the engineering industry. Students will be able to explain the theory behind signals and systems using mathematical tools such as Fourier, Laplace and Z-transforms for a variety of continuous-time and discrete-time systems. Having successfully completed this unit, students will have enhanced their analytical skills, programming and simulation skills, design and test skills, and logical thinking and reasoning skills. Furthermore, the students will be able to understand how to forecast and evaluate the behaviour of a range of engineering systems. For example, the students will design proportional, integral and derivative (PID) controllers and filters, and apply impulse, step, ramp, exponential and sinusoidal test signals to analyse time and frequency responses.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Examine the behaviours and applications of continuous-time and discrete-time signals in engineering systems

LO2 Formulate Fourier and Laplace transforms to analyse continuous-time signals and systems

LO3 Formulate discrete-time Fourier transforms and Z-transforms to analyse discrete-time signals and systems

LO4 Analyse applications of signals and systems using MATLAB based on the accuracy levels of the transmitted information.

Essential Content

LO1 **Examine the behaviours and applications of continuous-time and discrete-time signals in engineering systems**

Types of signals:

Continuous-time and discrete-time signals, periodic and aperiodic signals, signal energy and power, even and odd (symmetric and antisymmetric) signals, causal and non-causal signals, unit impulse, unit step, unit ramp, exponential and sinusoidal signals, time shifting, reversal and scaling.

Overview of continuous and discrete systems:

Interconnection of systems, basic system properties, differential equation model, classification of systems, convolution, system response and stability.

Properties of Fourier series:

Fourier series representation of continuous-time periodic signals, properties of continuous-time Fourier series, Fourier series representation of discrete-time periodic signals, properties of discrete-time Fourier series.

Applications of signals and systems:

Communication systems, energy generation, biomedical engineering, control systems, chemical process control, speech processing, circuit design, aeronautics and astronautics, acoustics and seismology.

LO2 **Formulate Fourier and Laplace transforms to analyse continuous-time signals and systems**

Continuous-time Fourier transforms:

Definition, representation of aperiodic signals, the continuous-time Fourier transform, properties of the continuous-time Fourier transform, convolution properties, multiplication properties and applications of the continuous-time Fourier transform.

Laplace transforms:

Definition, region of convergence, the inverse Laplace transform, properties of the Laplace transform, analysis and characterisation of linear time-invariant (LTI) systems using the Laplace transform, transfer functions, first- and second-order systems responses, transfer function algebra, block diagram representations and applications of Laplace transform.

LO3 **Formulate discrete-time Fourier transforms and Z-transforms to analyse discrete-time signals and systems**

Discrete-time Fourier transforms:

Definition, representation of aperiodic signals, the discrete-time Fourier Transform, properties of the discrete-time Fourier transform, convolution properties, multiplication properties and applications of the discrete-time Fourier transform.

Z-transforms:

Definition, region of convergence, the inverse Z-transform, properties of the Z-transform, analysis and characterisation of LTI systems using Z-transforms, Z-transfer functions, Z-transfer function algebra, block diagram representations and applications of the Z-transform.

LO4 **Analyse applications of signals and systems using MATLAB based on the accuracy levels of the transmitted information.**

Design and test of feedback control systems using MATLAB:

Linear feedback control systems, PID control of a system to understand system dynamics, impulse, step, ramp, exponential and sinusoidal response, time and frequency analysis, pole-and-zero analysis.

Design and test of filters using MATLAB:

Analogue and digital filters, low-pass, high-pass, band-pass and band-stop filters, finite-duration impulse response (FIR) and infinite-duration impulse response (IIR) filters, impulse, step, ramp, exponential and sinusoidal response, time and frequency analysis.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine the behaviours and applications of continuous-time and discrete-time signals in engineering systems</td><td rowspan="4">LO1 and LO2
D1 Evaluate the usefulness of the Fourier and Laplace transforms for analysing continuous-time signals and systems.</td></tr>
<tr><td>P1 Analyse the classifications and operations of continuous signals.
P2 Analyse the classifications and operations of discrete-time signals.</td><td>M1 Compare the applications of continuous-time and discreet-time signals in engineering systems.</td></tr>
<tr><td colspan="2">LO2 Formulate Fourier and Laplace transforms to analyse continuous-time signals and systems</td></tr>
<tr><td>P3 Investigate the properties of the continuous-time Fourier transform.
P4 Investigate the properties of the Laplace transform.</td><td>M2 Manipulate the continuous-time Fourier and Laplace transforms to solve complex engineering problems.</td></tr>
<tr><td colspan="2">LO3 Formulate discrete-time Fourier transforms and Z-transforms to analyse discrete-time signals and systems</td><td rowspan="4">LO3 and LO4
D2 Assess the time and frequency response of the PID controller, and IIR and FIR filters, and use the Fourier transform to justify the accuracy of the collected results and draw meaningful conclusions.</td></tr>
<tr><td>P5 Analyse the properties of the discrete-time Fourier transform.
P6 Analyse the properties of the Z-transform.</td><td>M3 Construct discrete-time Fourier transforms and Z-transforms to solve complex engineering problems.</td></tr>
<tr><td colspan="2">LO4 Analyse applications of signals and systems using MATLAB based on the accuracy levels of the transmitted information.</td></tr>
<tr><td>P7 Design a PID controller for a complex engineering system using MATLAB.
P8 Design IIR and FIR filters for a complex engineering system using MATLAB.</td><td>M4 Test the response of the PID controller, and IIR and FIR filters using impulse, step, ramp, exponential and sinusoidal inputs.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Chaparro, L. and Akan, A. (2018) *Signals and Systems using MATLAB.* 3rd Ed. Academic Press.

Kamen, E.W. and Heck, B.S. (2013) *Fundamentals of Signals and Systems using the Web and MATLAB*. 3rd Ed. Pearson.

Karris, S.T. (2003) *Signals and Systems with MATLAB® Applications.* 2nd Ed. Orchard Publications.

Nise, N.S. (2020) *Control Systems Engineering*. 8th Ed. John Wiley & Sons.

Oppenheim, A.V. and Verghese, G.C. (2017) *Signals, Systems and Inference.* Global Ed. Pearson.

Oppenheim, A.V., Willsky, A.S., and Nawab, S.H. (2013) *Signals and Systems*. 2nd Ed. Pearson.

Poularikas, A.D. (2018) *Transforms and Applications Primer for Engineers with Examples and MATLAB®*. CRC Press.

Sundararajan, D. (2009) *A Practical Approach to Signals and Systems.* John Wiley & Sons.

Websites

Refer to the relevant Subject Page on HNGlobal for suitable web resources for this unit.

http://www.ocw.mit.edu	MIT OpenCourseWare 'Signals and Systems' (Tutorials)
http://www.mathworks.com	MathWorks 'MATLAB and Simulink for Signal Processing' (General reference)
http://www.mathworks.com	MathWorks 'Solutions (MATLAB and Simulink)' (General reference)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

IEEE Transactions on Signal Processing

IEEE Signal Processing Magazine

Journal of Signal Processing Systems (Springer)

Links

This unit links to the following related units:

Unit 4015: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 4016: Instrumentation and Control Systems

Unit 4030: Industry 4.0

Unit 5021: Further Control Systems Engineering.

Unit 5043: Digital System Design

Unit Code: **R/650/2985**

Level: **5**

Credits: **15**

Introduction

Computer systems are deeply embedded in today's society, such that we are heavily dependent on this technology. Our transport, communications, financial and entertainment systems (to name but a few) are designed using complex digital circuits. These are usually based either on microprocessors/microcontrollers or on field-programmable gate arrays (FPGAs)/application-specific integrated circuits (ASICs). It is therefore essential that technicians and engineers who are trained in electronic or computer systems engineering have knowledge and skills in digital systems, particularly when working in embedded environments.

To study this unit, students are expected to have prior knowledge of functional building blocks involving combinational and sequential logic, and be able to use a development environment to write hardware description language (HDL) code to describe such functions. They should also be able to implement and verify the operation of these circuits using a FPGA development board.

This unit builds on student knowledge of digital circuits and their implementation within programmable technology (FPGAs). It starts by considering medium-scale building blocks and sequential systems (counters, shift registers, etc.) and the techniques used in the design of such circuits. The design, implementation and testing of more complex sequential systems are then studied by way of finite-state machines (FSMs). These are designed and simulated using HDL and computer-aided design (CAD) tools and then implemented in hardware using a FPGA development board.

On successful completion of this unit, students will be able to implement full simulations of combinational and sequential digital designs. They will be able to use appropriate tools (traditional and CAD) to design, implement and test FSMs. This will provide students with the knowledge, understanding and skills to progress to further study in higher education or to take up a technician/design role in industry.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Implement shift registers and mod-*n* counters using an HDL and FPGA development board

LO2 Synthesise medium-complexity digital circuits using structural HDL descriptions

LO3 Design finite-state machines (FSMs)

LO4 Implement FSMs by applying CAD tools and by using a FPGA development board.

Essential Content

LO1 Implement shift registers and mod-*n* counters using an HDL and FPGA development board

Overview of implementation strategies:

Implementation strategies of combinational circuits and logic minimisation; for example, review of first canonical form, 5- and 6-variable Karnaugh maps, Quine McCluskey (QM) method, multi-output minimisation, comparison of QM method with Karnaugh maps.

Shift registers:

Shift registers for parallel-in/parallel-out and serial-in/serial-out operations

Shift registers for serial-to-parallel and parallel-to-serial conversions

Simple sequence detectors

Control inputs: clear, set, direction, enable, and so on.

Counters:

Mod-*n* (divide-by-*n*) counters

Control inputs: clear, set, direction, and so on.

Testing digital circuits:

Importance of testing

Testing methodologies using HDL development tools

Test benches for shift registers and counters

Design for testability: built-in self-test, boundary scan, ensure effective use of tools and techniques when securely operating and testing digital systems and so on

Testing on a FPGA development board.

LO2 Synthesise medium-complexity digital circuits using structural HDL descriptions

Structural HDL methods:

Structuring digital designs

Structured design for test

Principles of structural HDL designs: concepts of components, instantiation.

Medium-complexity circuits:

For example, clock divider driving cascaded counters

Use of pre-designed library blocks; for example, LPMs (library of parameterised modules), and so on.

LO3 **Design finite-state machines (FSMs)**

Finite-state machines (FSMs):

Definition, Moore and Mealy models

Use of design techniques: algorithmic state machine (ASM) charts, state-transition diagrams, state-transition tables, state allocation and minimisation, state equations.

FSM descriptions in an HDL:

Methods of describing FSMs in an HDL

Behavioural and/or structural descriptions

Test benches.

LO4 **Implement FSMs by applying CAD tools and by using a FPGA development board.**

CAD tools:

Specialist FSM design and optimisation tools within HDL development environments.

Design for test and manufacture:

Controllability, observability and testability; automatic test pattern generation (ATPG); CAD simulation tools – event-driven simulation, timing simulation

Fault simulation principles and fault modelling.

FPGA development boards:

Structure of a typical development board

Downloading designs to a development board

Functional testing and verification of designs.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Implement shift registers and mod-*n* counters using an HDL and FPGA development board		
P1 Implement shift registers and mod-*n* counters in an HDL. **P2** Explain simulation and physical testing methods applicable to HDL-designed shift register and counter, using examples.	**M1** On a FPGA development board, implement fully simulated shift registers and mod-*n* counters with control inputs.	**D1** Critically appraise the function of shift registers and mod-*n* counters with control inputs that have been simulated using test benches and implemented on a FPGA development board.
LO2 Synthesise medium-complexity digital circuits using structural HDL descriptions		
P3 Design digital circuits that use structural HDL with at least two components. **P4** Synthesise sequential circuits that use at least one pre-designed component block from within an HDL development system.	**M2** Design medium-complexity digital circuits that use structural HDL with at least three components. **M3** Synthesise medium-complexity sequential circuits that use several pre-designed component blocks from within an HDL development system.	**D2** Synthesise medium-complexity sequential circuits that use several pre-designed component blocks from within an HDL development system and also employ user-designed blocks.
LO3 Design finite-state machines (FSMs)		
P5 Design a simple state machine using either a Moore or a Mealy model. **P6** Verify the operation of a state machine using a test bench.	**M4** Design state machines using ASM, Moore and Mealy models. **M5** Analyse the operation of a state machine using a test bench.	**D3** Critically evaluate fully optimised, simulated and tested state machines that have been designed using a variety of models and techniques.
LO4 Implement FSMs by applying CAD tools and by using a FPGA development board.		
P7 Describe a simple state machine using behavioural HDL. **P8** Implement a simple state machine using a FPGA development board.	**M6** On a FPGA development board, implement state machines that have been designed using: a) behavioural HDL; b) specialist state machine design software.	**D4** Critically compare the implementation of fully optimised state machines that have been designed using: a) behavioural HDL; b) specialist state machine design software.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Floyd, T.L. (2015) *Digital Fundamentals*. 11th Ed. Pearson.

Kleitz, W. (2014) *Digital Electronics: A Practical Approach with VHDL*. 9th Ed., Pearson New International Edition. Pearson Education.

Mano, M.M. and Ciletti, M.D. (2022) *Digital Design: With an Introduction to the Verilog HDL, VHDL and SystemVerilog*. 6th Ed. Pearson.

Mano, M.R., Kime, C.R. and Martin, T. (2016) *Logic and Computer Design Fundamentals*. 5th Ed., Global Edition. Pearson.

Short, K. (2014) *VHDL for Engineers*. Pearson New International Edition. Pearson Education.

Websites

http://www.intel.com	Intel 'Intel® FPGA Academic Program' (General reference)
http://www.xilinx.com	Xilinx 'Xilinx University Program' (General reference)

Links

This unit links to the following related units:

Unit 4064: Analogue and Digital Electronics

Unit 4067: Digital Devices and Systems

Unit 5044: Digital Electronic Systems.

Unit 5044: Digital Electronic Systems

Unit Code: **T/650/2986**

Level: **5**

Credits: **15**

Introduction

Digital systems are now deeply embedded in today's society, such that we are heavily dependent on this technology. Our transport, communications, financial and entertainment systems (to name but a few) depend on digital circuits, and these are often extremely complex. It is therefore essential that technicians and engineers who are trained in any of the branches of electrical/electronic engineering or automation have knowledge and skills in digital systems. During the past two decades the use of programmable technology has expanded rapidly such that it is now the predominant method of implementing complex digital circuits. Such circuits are found in our mobile phones, display technologies, gaming systems, laser printers, and so on. In this unit, students use this exciting technology in combination with computer-aided design (CAD) to design and implement circuits, thereby preparing them to meet the demands of many roles within the electronics sector.

This unit introduces digital systems in the form of functional building blocks using combinational and sequential logic. It then considers design techniques to build more complex functions. Most modern digital designs are now implemented with programmable technologies such as field-programmable gate arrays (FPGAs) and application-specific integrated circuits (ASICs), rather than the traditional small-scale and medium-scale integrated circuits (SSIs and MSIs, respectively). This unit focuses on the design and development of digital circuits using CAD tools and a hardware description language (HDL). Physical implementation of these designs is carried out on a FPGA development board.

To study this unit, students are expected to have a prior understanding of logic functions and be able to use tabular and Karnaugh map techniques to design simple logic systems.

On successful completion of this unit, students will understand the core concepts of digital systems and be able to identify the most common digital building blocks, using them in conjunction with traditional design techniques to build more complex digital functions. Students will be able to use an HDL and programmable logic to design and implement more complex circuits on a FPGA, providing them with the knowledge, understanding and skills to progress to further study in higher education or to take up a technician role in industry.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Evaluate combinational logic circuit designs for complex applications

LO2 Evaluate sequential logic circuit designs for complex applications

LO3 Implement complex combinational and sequential logic circuits using an HDL

LO4 Analyse the function of combinational and sequential logic designs using simulation, and testing on a FPGA development board.

Essential Content

LO1 **Evaluate combinational logic circuit designs for complex applications**

Overview of combinational logic gates:

Symbols, truth tables, Boolean equations, function of basic logic gates: AND, OR, NOT, XOR, NAND, and NOR.

Overview of techniques used in combinational logic circuit design:

Boolean algebra, De Morgan's theorems, Karnaugh mapping.

Overview of digital technologies:

Historical use of CMOS and TTL: speed, voltages, power consumption, packing density; recent silicon technologies

Concept of propagation delay and its implications, timing analysis of combinational circuits.

Combinational logic design:

Circuits using logic gates to achieve more complex functions (e.g. *n*-bit adders, decoders, encoders, MUX/DEMUX (multiplexers/demultiplexers), parity checking, logic controls)

Design of optimised combinational circuits considering IC resources, gate count, propagation delays, and so on.

LO2 **Evaluate sequential logic circuit designs for complex applications**

Sequential logic design:

Sequential building blocks: D, T and JK flip-flops.

Clock signals:

Rise and fall times, voltage levels – impact on maximum clock speed, and so on

Set-up and hold times – implication on maximum clock speed.

Asynchronous and synchronous systems:

Compare synchronous and asynchronous counters, shift registers, and synchronous counters and sequence generators; simple state diagrams to describe counters and sequence generators.

Introduction to finite-state machines (FSMs):

Definition, Moore and Mealy models

Transition from circuit to FSM.

LO3 **Implement complex combinational and sequential logic circuits using an HDL**

Hardware description languages (HDLs):

Languages (VHDL and Verilog) – choose one to use

Structures − entity and architecture, and key words associated with the chosen language; behavioural architecture.

Combinational logic:

Entry of schematic and HDL (e.g. VHDL, Verilog) into HDL development software (e.g. Quartus (Intel), ISE Design Suite (Xilinx)); compilation and debugging.

Sequential logic:

Complex designs (e.g. cascaded shift registers, mod-*n* counters, and sequence generators) written in HDL using dataflow and/or behavioural architecture.

LO4 **Analyse the function of combinational and sequential logic designs using simulation, and testing on a FPGA development board.**

Field-programmable gate array (FPGA) technology:

Introduction to structure and complexity of current FPGA technology.

Simulation:

Use of test benches and the inbuilt simulators of HDL development tools to simulate combinational and sequential designs.

Design for test and manufacture:

Controllability, observability and testability; automatic test pattern generation (ATPG); CAD simulation tools: event-driven simulation, timing simulation

Fault simulation principles and fault modelling.

FPGA development boards:

Structure of a typical development board

Pin assignment, downloading, simulation, testing and verifying combinational and sequential designs

Critical comparison of simulation results and physical testing results.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate combinational logic circuit designs for complex applications		
P1 Explain the techniques used in the design and analysis of digital circuits, making use of Boolean algebra and Karnaugh mapping. **P2** Evaluate the combinational logic circuit designs produced using Boolean algebra and Karnaugh mapping.	**M1** Design optimised combinational circuits for complex applications, making full use of Boolean algebra, De Morgan's theorems and Karnaugh mapping.	**D1** Critically evaluate optimised combinational circuit designs for complex applications, making full use of Boolean algebra, De Morgan's theorems and Karnaugh mapping and timing analysis.
LO2 Evaluate sequential logic circuit designs for complex applications		
P3 Design shift-register-based circuits for various applications using appropriate design techniques. **P4** Evaluate mod-*n* counter circuit designs produced making use of state diagrams and minimisation techniques.	**M2** Synthesise a variety of sequential logic circuits for complex applications using appropriate techniques to provide optimised designs.	**D2** Critically assess a variety of sequential logic circuits for complex applications using appropriate techniques to validate the efficiency of the optimised designs.

Pass	Merit	Distinction
LO3 Implement complex combinational and sequential logic circuits using an HDL		
P5 Implement combinational logic circuits for various applications using schematic entry and an HDL compiler. **P6** Rewrite given HDL designs for sequential systems to achieve additional functionality.	**M3** Develop combinational and sequential logic circuits using an HDL for complex applications.	**D3** Critically evaluate combinational and sequential logic circuits for complex applications that have been designed using an HDL.
LO4 Analyse the function of combinational and sequential logic designs using simulation, and testing on a FPGA development board.		
P7 Analyse the functionality of combinational logic circuits using simple simulation techniques and functional testing using a FPGA development board. **P8** Analyse the results of simulating given HDL sequential logic designs, and compare this with the functional performance on a FPGA development board.	**M4** Examine the functionality of combinational and sequential logic circuits by using a CAD simulator or a testbench, and compare this with the functional performance on a FPGA development board.	**D4** Critically analyse the functionality of combinational and sequential logic circuits for complex applications by using testbenches and comparing simulation results with functional performance on a FPGA development board.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Floyd, T.L. (2015) *Digital Fundamentals*. 11th Ed. Pearson.

Kleitz, W. (2014) *Digital Electronics: A Practical Approach with VHDL*. 9th Ed., Pearson New International Edition. Pearson Education.

Mano, M.M. and Ciletti, M.D. (2022) *Digital Design: With an Introduction to the Verilog HDL, VHDL and SystemVerilog*. 6th Ed. Pearson.

Roth, J.C.H and Joh, L.K. (2017) *Digital Systems Design Using VHDL.* 3rd Ed. Cengage Learning.

Short, K. (2014) *VHDL for Engineers*. Pearson New International Edition. Pearson Education.

Websites

http://www.intel.com	Intel 'Intel® FPGA Academic Program' (General reference)
http://www.xilinx.com	Xilinx 'Xilinx University Program' (General reference)

Lnks

This unit links to the following related units:

Unit 4019: Electrical and Electronic Principles

Unit 4020: Digital Principles

Unit 4064: Analogue and Digital Electronics

Unit 4067: Digital Devices and Systems

Unit 5043: Digital System Design.

Unit 5045: Electrical Engineering and Sustainability

Unit Code: Y/650/2987

Level: 5

Credits: 15

Introduction

As a multi-disciplinary collaborative challenge, sustainability puts the engineers of today and the future on the front line of creating a sustainable economy through sustainable engineering solutions. Sustainability includes environmental, social, economic and governance aspects. Environmental considerations concern not only atmospheric emissions but also land use and choice of materials, such as rare earth elements. Within this broad context, sustainable electrical engineering places heavy emphasis on developing sustainable sources of electricity, such as wind and solar power, and integrating sustainable power into the grid. The focus on sustainability also includes developing practical solutions for pervasive use, such as hybrid and electric vehicles and energy-efficient appliances, motors and heating and cooling systems.

This unit introduces the student to various topics in the electrical power sector that interlink systems and subsystems associated with sustainable power production and distribution. This includes the design and construction of sustainable energy sources, and design, installation and management of electrical power systems. The unit discusses devices and systems used to interconnect sustainable energy systems and conventional energy production devices to produce an integrated energy production system.

Engineers ranging from the craft technician to the Chartered Engineer should have an understanding and working knowledge of the power-related electrical domain in terms of sustainable power technologies because they underpin the principles of power production, delivery, distribution and use in the modern world, particularly when it comes to the development of energy production techniques in the context of sustainable power supply. The skills, knowledge and behaviours developed are relevant to multiple industries and a variety of engineering roles.

The learning outcomes of the unit are designed to ensure coverage of current and future developments in sustainable techniques of power production and how these connect to existing grid systems. The simulation of problem scenarios and solutions are also a focus of the learning outcomes, and on successful completion of the unit, students will have developed skills in theoretical research, mathematical modelling, data interpretation and practical experimentation.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Investigate sustainable energy source solutions used in power production that may be integrated into existing power systems

LO2 Explore the technical considerations involved when connecting sustainable energy sources to existing power systems

LO3 Analyse, by practical experimentation, sustainable power production technology and its interface with conventional power systems

LO4 Analyse, using appropriate simulation software, models of sustainable energy sources connected to conventional systems.

Essential Content

LO1 **Investigate sustainable energy source solutions used in power production that may be integrated into existing power systems**

Conventional energy sources:

Traditional power production systems using coal, gas, and nuclear

Common problems with traditional solutions, for example, sustainability, pollution, recycling

Environmental considerations, for example, carbon footprint, carbon capture.

Sustainable energy solutions for electrical engineering:

Sustainable versus renewable energy

Sources of sustainable energy

Solutions in common use, for example, wind turbine, solar energy, tidal and hydroelectric power, and their operating principles

Solutions in development, for example, gravity storage and battery storage and their operating principles

Power-to-X (e.g. power-to-fuel, power-to-gas, power-to-hydrogen, power-to-liquid, power-to-methane).

Efficacy of energy solutions and policy landscape:

The three pillars of sustainability: economic impact, environmental impact, social impact

Determine energy in various sources (e.g. wind, hydropower, tidal and wave, geothermal)

Top-down sustainability: change through regulation, system-level changes driven by policy and operational directives

Bottom-up sustainability: change through the market, islands of sustainability (IOS)

Sustainability policies (e.g. UK environmental and sustainability policy, US sustainable development policy, the US National Environmental Policy Act) and strategies (e.g. EU Sustainable Development Strategy)

Relevant case studies.

LO2 **Explore the technical considerations involved when connecting sustainable energy sources to existing power systems**

Sustainable energy power system characteristics:

Sustainable source energy output; heat, alternating current (AC) electricity, direct current (DC) electricity

Electricity distribution and grid systems: AC, DC grid; future trends, for example, micro generation, DC distribution

Electrical connection of sustainable energy devices to grid systems considering existing systems and future trends in distribution: rectification, inverters, synchronisation, transformers

Electrical storage methods in sustainable and conventional energy systems: hydro(electric)power, battery technology and future proposed methods, for example, gravity storage

Transmission line and cable analysis, voltage and phase-shift characteristics, energy losses.

LO3 **Analyse, by practical experimentation, sustainable power production technology and its interface with conventional power systems**

Practical analysis of sustainable energy devices:

Perform tests on sustainable energy devices; photovoltaic solar cells

AC machines: production of rotating field, principles of operation, induction motor, squirrel-cage and wound rotor construction, concept of slip, torque-speed characteristics, equivalent circuit

DC machines: principles of operation, separately exited, series and shunt machines, equivalent circuit, torque-speed and current speed curves, transformers

Obtain and analyse data: voltage, current, power input, power output, efficiency

Efficiency and sustainability of sustainable energy solutions: heat pumps, solar technology, rotating machines in wave, tidal and wind turbine applications.

Overview of power electronics in developing sustainable solutions:

Power electronic/semiconductor devices (e.g. diodes, bipolar transistors, insulated-gate bipolar transistor (IGBT), metal–oxide–semiconductor field-effect transistor (MOSFET), silicon-controlled rectifier (SCR)) and future developments

Applications of electronic/semiconductor devices.

LO4 **Analyse, using appropriate simulation software, models of sustainable energy sources connected to conventional systems.**

Subsystem simulation models:

Overview of modelling of electronic devices (e.g. MOSFETs, SCRs, IGBTs)

AC and DC machines

Transformers

Simulation software models, for example, MATLAB, Simscape Electrical.

Simulation models:

Wind generation systems, microgeneration systems, photovoltaic systems, systems with battery storage

Operation and efficiency/performance of such systems

Simulation software models, for example, MATLAB, Simscape Electrical.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate sustainable energy source solutions used in power production that may be integrated into existing power systems		
P1 Discuss a range of sustainable energy solutions currently in use and in development, including sustainability ratings. **P2** Investigate the various methods required to connect sustainable energy solutions to the existing power system.	**M1** Evaluate the efficiency of typical sustainable energy solutions.	**D1** Critically evaluate the effectiveness of typical energy solutions and compare to conventional solutions in terms of sustainability.
LO2 Explore the technical considerations involved when connecting sustainable energy sources to existing power systems		
P3 Explore technical considerations of a variety of sustainable energy solutions. **P4** Examine methods of connecting sustainable sources to existing systems.	**M2** Evaluate methods of connecting sustainable energy sources to existing grid systems.	**D2** Critically evaluate interface methods, considering future trends in electrical distribution technology.

Pass	Merit	Distinction
LO3 Analyse, by practical experimentation, sustainable power production technology and its interface with conventional power systems		
P5 Operate the common sustainable power generation devices in practical situations for successful outcomes. **P6** Investigate a range of switching devices, power converters, rectifiers and drives used in industrial applications.	**M3** Critically analyse the operation and characteristics of AC and DC rotating machines, including the advantages and disadvantages of typical switching devices.	**D3** Evaluate, in terms of efficiency, the effectiveness of rotating machines, solar and heat pump technologies, electronic devices and their likely applications in sustainable energy systems.
LO4 Analyse, using appropriate simulation software, models of sustainable energy sources connected to conventional systems.		
P7 Implement analysis of DC voltage source, AC voltage source, AC current source, and controlled voltage source. **P8** Test any given models for power generation systems, including commentary on test outcomes.	**M4** Design a DC current source to a given requirement.	**D4** Redesign an existing model of a power generation system based on a given scenario.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Chapman, S.J. (2005) *Electric Machinery Fundamentals*. 4th Ed. McGraw Hill.

Everett, B., Peake, S. and Warren, J.P. (2021) *Energy Systems and Sustainability: Power for a Sustainable Future*. 3rd ed. Oxford University Press.

Gonen, T. (2012) *Electrical Machines with MATLAB*. 2nd Ed. CRC Press.

Masters. G.M. (2004) *Renewable and Efficient Electric Power Systems*. 2nd Ed. Wiley/IEEE Press.

Perelmuter, V. (2017) Renewable Energy Systems: Simulation with Simulink and SimPowerSystems. CRC Press.

Rashid, H.R. (2014) Power Electronics, Devices, Circuits and Applications. 4th Ed. Pearson.

Rashid, M.H. (2017) *Power Electronics Handbook.* 4th Ed. Butterworth-Heinemann.

Wildi, T. (2006) Electrical Machines, Drives, and Power Systems. 6th Ed. Pearson.

Websites

ietresearch.onlinelibrary.wiley.com	The Institution of Engineering and Technology 'IET Renewable Power Generation journal' (Research)
http://www.youtube.com/c/matlab	MATLAB YouTube 'Performing Power System Studies' (Tutorials)

Links

This unit links to the following related units:

Unit 4021: Electrical Machines

Unit 4026: Electrical Systems and Fault Finding

Unit 5011: Industrial Power, Electronics and Storage

Unit 5018: Sustainability

Unit 5019: Further Electrical, Electronic and Digital Principles

Unit 5020: Utilisation of Electrical Power.

Unit 5046: Analogue and Digital Communications

Unit Code: A/650/2988

Level: 5

Credits: 15

Introduction

Communication systems is a dynamic and rapidly growing field of study owing to an ever wider range of applications, including mobile phones, TV broadcast, computer networks, Wi-Fi, the Internet of Things (IoT), connected vehicles and smart cities. Communication systems consist of different nodes and links that enable exchange of information such as voice, video, image and data. The key elements of a communication system are a transmitter, a communication medium and a receiver. The main challenge in a communication system is to eliminate noise and interference, which degrades its performance. Securing communication channels is a further significant challenge of increasing importance.

This unit introduces the fundamentals of communication systems, including analogue and digital communication techniques. The unit starts with basic communication theories, including techniques for modulation and demodulation. It considers the factors that impair signals in communication media, including noise and interference. The unit further covers the physical practicalities of communication systems, such as guided and unguided transmission media.

It is an essential prerequisite that students have successfully completed *Unit 4064: Analogue and Digital Electronics* or an equivalent.

On successful completion of this unit, students will have gained knowledge of the different blocks used in a communication system. They will be able to examine different modulation and demodulation techniques in both the analogue and digital domains, and will be able to analyse transmitted and received signals used in different media. Students will also have sufficient knowledge of security protocols to secure a communication system. Finally, students will be able to design a communication system in a simulation environment.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Examine the different performance metrics and components used in a communication system

LO2 Explore different modulation and demodulation techniques

LO3 Investigate the transmission of signals over wired and wireless media

LO4 Design a communication system.

Essential Content

LO1 **Examine the different performance metrics and components used in a communication system**

Signals, noise and communication blocks:

Communication system blocks, including signal sources, signal sinks, channels; composite signals, signal spectrum, types of signals, bandwidth, bit error rate (BER).

Noise:

Types of noise, such as thermal noise, shot noise, flicker noise; impact of external noise in different communication media, interference, signal-to-noise ratio, noise figure, additive white Gaussian noise (AWGN).

Signal representations:

Concept of orthogonality, frequency content of signals, types of spectrum, bandwidth, measurement and calibration of signals; distortion and filtering, practical filter types and characteristics.

LO2 **Explore different modulation and demodulation techniques**

Analogue modulation and demodulation:

Amplitude modulation (AM) and demodulation, different methods such as single-sideband suppressed-carrier (SSB-SC) and double-sideband suppressed carrier (DSB-SC), mathematical equation of AM, modulation index, modulator and demodulator block diagram both for coherent and non-coherent detection method

Frequency modulation (FM) and demodulation, narrowband and wideband FM, FM spectrum, block diagram of modulator, demodulators such as phased-lock loops (PLLs), slope detection, etc.

Baseband digital transmission:

Pulse-code modulation (PCM) and demodulation, Nyquist–Shannon sampling theorem, aliasing, different line-coding techniques including return to zero (RZ), non return to zero (NRZ), Manchester, differential Manchester, alternate mark inversion (AMI) and high-density bipolar order 3 (HDB3).

Digital modulation and demodulation:

Amplitude-shift keying (ASK), frequency-shift keying (FSK) and phase-shift keying (PSK) including modulator and demodulator block diagram, differential phase-shift keying (DPSK), introduction to multilevel modulation including quadrature phase-shift keying (QPSK) and quadrature amplitude modulation (QAM).

Test modulation and demodulation:

Use of lab to test approaches to modulation and demodulation.

LO3 **Investigate the transmission of signals over wired and wireless media**

Types of media:

Guided: copper wire, twisted pair, coaxial cable, fibre optics, power-line carrier, advantages and disadvantages of different wired media

Unguided: infrared, radio wave; propagation mechanism, propagation delay, attenuation, microwaves, lasers, ionosphere layers, satellite radio.

Fibre-optic communication:

Optical fibres, spectrum of operation, fibre-optic construction, total internal reflection, different types of fibre-optic cable, optical transmitters, optical receivers, optical path loss calculation.

Wireless communication:

Radio propagation, frequency bands, antennas and antenna types including isotropic, dipole, monopole, Yagi and dish ; antenna gain, free-space path loss calculation, satellite communication, types of satellite orbit.

Security:

Importance of secured network, different security threats, security standards including ISO27002, IEC-62443.

LO4 **Design a communication system.**

Plan and design:

Define the communication system problem

Specify requirements, including identification of important characteristics to show success of the communication system design.

Implement:

Build a communication system design in a simulation environment using commercially available software (e.g. MATLAB/Simulink or similar), to include signal source, modulation block, channel, demodulation block and sink; performance analysis.

Evaluate:

Test, redesign, refine, improve and evaluate communication system design.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine the different performance metrics and components used in a communication system</td><td rowspan="4">LO1 and LO2

D1 Justify which modulation technique would perform better in a given scenario in terms of both bandwidth and noise performance.</td></tr>
<tr><td>P1 Analyse the different communication blocks used in a communication system.

P2 Examine types of noise, their sources and their effects on communication systems.</td><td>M1 Evaluate different performance metrics used in communication systems.</td></tr>
<tr><td colspan="2">LO2 Explore different modulation and demodulation techniques</td></tr>
<tr><td>P3 Compare different techniques to modulate and demodulate both analogue and digital signals.

P4 Explore pulse-code modulation and line-coding techniques.</td><td>M2 Critically examine modulation techniques used in modern communication systems.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Investigate the transmission of signals over wired and wireless media		**LO3 and LO4**
P5 Investigate different media available for transmission of signals, both guided and unguided. **P6** Explore the operation principles of optical and wireless communication. **P7** Investigate communication system security issues and methods of mitigating risk.	**M3** Analyse the performance of optical and wireless communication by conducting path loss analysis.	**D2** Critically evaluate the transmission of signals over wired and wireless media via the communication system designed, and communicate results.
LO4 Design a communication system.		
P8 Plan a communication system. **P9** Design and simulate a communication system for a given scenario using simulation tools, such as MATLAB/Simulink or similar commercially available software. **P10** Test the designed communication system and communicate results.	**M4** Refine the design of the simulated communication system to enhance performance and communicate results.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Essential:

Lathi, B.P. and Ding, Z. (2019) *Modern Digital and Analog Communication Systems.* 5th Ed. Oxford University Press.

Recommended:

Beasley, J.S. and Miller, G.M. (2013) *Modern Electronic Communication*. 9th Ed., New International Edition. Pearson.

Otung, I. (2021) *Communication Engineering Principles*. 2nd Ed. Wiley.

Additional:

Goleniewski, L. (2007) *Telecommunications Essentials* (K.W. Jarrett, Ed.). 2nd Ed. Addison-Wesley.

Websites

www.ieee.org	Institute of Electrical and Electronics Engineers 'IEEE Xplore Digital Library' (General reference)
http://www.mathworks.com	MathWorks 'Communications Toolbox' (Development tool)

Links

This unit links to the following related units:

Unit 4002: Engineering Maths

Unit 4064: Analogue and Digital Electronics.

Unit 5047: Computer Architecture and Interfacing

Unit Code: D/650/2989

Level: 5

Credits: 15

Introduction

Computer architecture is an important aspect of computer systems engineering, whereby application requirements are translated into processor designs. Processors can be deployed in high-performance computing (HPC) clusters, laptops, mobile phones and embedded systems, and cover a range of computational requirements; for example, graphics processing and artificial intelligence (AI). The type of environment and the power available within it exert a major impact on the design and implementation of modern computer architectures. Computer architecture engineers work in many areas, including the Internet of Things (IoT), telecommunications, defence and automotive.

This unit provides students with an appreciation of the relationship between software, compilers and instruction set architectures (ISAs), enabling them to review the main ISA types and their impact on the microarchitecture; for example, design of decoders and processor pipelines and analysis of the design trade-offs between complexity, power and frequency. The unit will also cover memory hierarchy, including virtual memory and caches, and the main components of system-on-chip (SoC); for example, multicores, interconnects, interrupt handlers, power management, clock domains, and memory controllers. Students will also acquire an understanding of advanced power management, including power domains and frequency scaling, and interface standards using high- and low-speed signalling.

On successful completion of this unit, students will have gained insights into both the theoretical and practical underpinnings of the design of modern computer systems. They will understand the main components and design philosophy behind modern SoC implementations. Students will learn by creating simple assembly programs targeting an ISA, and will review documentation to develop an understanding of the impact of the underlying microarchitecture and its implementation of the developed code. Students will also gain familiarity with interpreting complex specification documents and be capable of presenting a critical evaluation of different architectural approaches.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Produce an assembly language application targeting a chosen instruction set architecture (ISA) to meet a set of application requirements

LO2 Analyse microarchitectural approaches for target application domains to meet specified design requirements

LO3 Examine the key components used in the implementation of modern system-on-chip (SoC)

LO4 Investigate the techniques used to interface with modern processors.

Essential Content

LO1 **Produce an assembly language application targeting a chosen instruction set architecture (ISA) to meet a set of application requirements**

Application design:

Translate high-level application requirements to produce formal instruction set architecture (ISA) requirements: memory protection; addressing modes; data types, for example, floating point, fixed point, reduced precision

Net zero for efficient computer architectures

Review ISAs to determine suitability for given application requirements: open- or closed-source ISAs, reduced instruction set computer (RISC), complex instruction set computer (CISC), very long instruction word (VLIW), quantum computer architecture (QCA)

Relate code density to memory and bandwidth requirements, impact of compressed instruction formats.

Implement and test applications:

Implement assembly language applications targeting industry-standard ISAs, for example, X86_64, AARCH64, RISC-V

Test assembly language applications using simulation tools or hardware; observe the impact of instructions on the architectural state in the simulator or on hardware interfaced with external devices, for example, a universal asynchronous receiver/transmitter (UART)

Identify the relationship between compiler and ISA

Managing hardware and software interrupts and exceptions, for example, responding to input/output (I/O) changes, memory access errors.

LO2 Analyse microarchitectural approaches for target application domains to meet specified design requirements

Processor architecture:

Processor pipelining, superscalar approaches and simultaneous multithreading (SMT), core functional units, for example, instruction fetch, decoder, arithmetic logic unit (ALU), floating-point units, write back

Frequency, power, and area considerations, including combinatorial negative slack

Endianness

Integrated circuit (IC) types: general-purpose central processing unit (CPU), field-programmable gate array (FPGA), digital signal processor (DSP), graphics processing unit (GPU), artificial intelligence accelerator.

Memory arrangements:

Memory hierarchy and cache arrangements in modern processors with reference to Harvard and von Neumann architectures; data-flow processors; virtual memory management, memory management unit (MMU) prefetching, branch prediction, effects of branch misprediction.

Application domains:

Microarchitecture use, for example, automotive, mobile phones, laptops, high-performance computing (HPC), space Microarchitectures, to include power, heterogeneity, redundancy, and geopolitical impact of the ISA and underlying technology licensing.

LO3 **Examine the key components used in the implementation of modern system-on-chip (SoC)**

Main IP blocks:

Identify the main components of a SoC, for example, direct memory access (DMA), memory controllers, multi/heterogeneous cores, caches, interconnects, boot ROM, graphics processing unit (GPU), input/output (IO), debug, interrupts, clock controls, static random-access memory (SRAM), watchdog timer (WDT) and input/output memory management unit (IOMMU)

Techniques to reduce power usage, for example, dynamic power and frequency scaling, clock gating, dark silicon.

On-chip interconnects:

Network-on-chip, crossbars, on-chip bus protocols, for example, Advanced eXtensible Interface (AXI), Wishbone

Static random-access memory (SRAM) interfaces

Protocol bridging, buffers, head-of-line blocking

Processor address space, cache coherency.

Security considerations:

Trusted Platform Module (TPM), trusted execution mode, side-channel attacks, privilege levels; types of security threats and impact (e.g,, IT infrastructure assets and network related threats linked to installation, configuration, maintenance and management aspects).

LO4 **Investigate the techniques used to interface with modern processors.**

Peripheral interfaces:

Low-speed interfacing, for example, universal asynchronous receiver/transmitter (UART), Serial Peripheral Interface (SPI), I^2C

Processor debugging, for example, Joint Test Action Group (JTAG)

High-speed interfacing, for example, Universal Serial Bus (USB), Peripheral Component Interconnect (PCI)

Memory interface standards, for example, double data rate synchronous dynamic random-access memory (DDR SDRAM), High Bandwidth Memory

3D stacking, chiplets.

Interconnection of processors and accelerators:

Cache coherent processor interconnects, for example, Cache Coherent Interconnect for Accelerators (CCIX), Compute Express Link (CXL)

NVLink, chiplets

Differential signalling, SerDes encoding

High-speed interfacing to FPGAs, for example, Aurora.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Produce an assembly language application targeting an instruction set architecture (ISA) to meet a set of application requirements		
P1 Design an assembly language application to meet a given set of requirements. **P2** Develop and test an assembly language application to meet the requirements of produced designs.	**M1** Detail the improvements made to an assembly language application, referencing ISA documentation.	**D1** Evaluate the design and development of applications to accommodate interrupts and exceptions.
LO2 Analyse microarchitectural approaches for target application domains to meet specified design requirements		
P3 Analyse the impact of pipeline depth in relation to frequency and area. **P4** Compare the key microarchitectural design considerations for different application domains.	**M2** Evaluate the approaches used to mitigate memory access latency.	**D2** Evaluate recent developments in ISA and microarchitecture development.
LO3 Examine the key elements used in the implementation of modern system-on-chip (SoC)		**LO3 and LO4**
P5 Investigate the main components of a modern SoC. **P6** Examine the approaches used to interconnect components securely within a SoC.	**M3** Discuss the techniques used to reduce power consumption within a SoC.	**D3** Explore chip-to-chip and chip-to-accelerator connectivity, including cache coherency protocols and associated SoC-level components.
LO4 Investigate the techniques used to interface with modern processors.		
P7 Choose appropriate interfaces to meet design requirements. **P8** Describe approaches used at system level to increase bandwidth and reduce memory access latency.	**M4** Discuss the impact of high-speed signalling on system design.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Grandinetti, L., Joubert, G.R., Michielsen, K., Mirtaheri, S.L., Taufer, M. and Yokota, R. (Eds.) (2019) *Future Trends of HPC in a Disruptive Scenario*. IOS Press.

Greaves, D.J. (2014) *Modern System-on-Chip Design on Arm*. Arm Education Media.

Hennessy, J.L. and Patterson, D.A. (2017) *Computer Architecture: A Quantitative Approach*. Morgan Kaufmann.

Kaye, P., Laflamme, R. and Mosca, M. (2007) *An Introduction to Quantum Computing*. Oxford University Press.

Shen, J.P. and Lipasti, M.H. (2013) *Modern Processor Design: Fundamentals of Superscalar Processors*. Waveland Press.

Stallings, W., Zeno, P. and Jesshope, C.R. (2016) *Computer Organization and Architecture: Designing for Performance*. 10th Ed. Pearson.

Yanofsky, N.S. and Mannucci, M.A. (2008) *Quantum Computing for Computer Scientists*. Cambridge University Press.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Davidson, S., Xie, S., Torng, C., Al-Hawai, K., Rovinski, A., Ajayi, T., Vega, L., Zhao, C., Zhao, R., Dai, S. and Amarnath, A. (2018) The Celerity open-source 511-core RISC-V tiered accelerator fabric: Fast architectures and design methodologies for fast chips. *IEEE Micro*, 38(2), 30–41.

Links

This unit links to the following related units:

Unit 4061: Programming for Engineers

Unit 4065: Internet and Network Technologies

Unit 4066: Data and Information

Unit 5049: Data Networks, Services and Security

Unit 5050: Machine Learning Systems and Programming.

Unit 5048: Sensors and Automation

Unit Code: J/650/2990

Level: 5

Credits: 15

Introduction

Modern developments and applications of automation in industry rely on complex and highly reliable industrial communication networks. Industrial communication is typically a mixture of multilayered, multidimensional networks involving fieldbuses, software packages, media, and a host of other tools. To be able to install, commission, maintain and troubleshoot an industrial plant, a competent engineer requires a good understanding of sensor and actuator technologies and core communication technologies. This unit equips students with the requisite knowledge of sensors and actuators and the key skills underpinning popular industrial communication networks, such as PROFINET, Ethernet IP, Modbus, IO Link and EtherCAT, thereby extending the breadth of employment to which students pursuing a career in network technologies can aspire.

Thus, this unit aims to provide students with the skills and competencies required to work in the areas of industrial computer control, automation, and Industry 4.0. Fundamental concepts underpinning the use of sensors and industrial communication networks for automation are introduced, and students are given the essential knowledge and skills required for the use of Ethernet-based technology in support of real-time industrial network environments. An appreciation of technologies using wire pairs, fibre optics, satellites and microwave transmission will be provided. The unit will provide specialist knowledge for work with industrial controllers (e.g. programmable logic controllers (PLCs)) in the areas of manufacturing and automation using popular network technologies such as PROFINET, together with an appreciation of security aspects in relation to network- and cloud-based solutions.

On successful completion of this unit, students will have gained knowledge and skills in the application of PLCs to industrial control, and the design, development and evaluation of Ethernet-based communication and automation systems. Through appropriate tasks and assignments, students will be exposed to good engineering practices in software engineering, and in the installation, testing and maintenance of networked automation systems.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Explore computer control in a feedback configuration

LO2 Examine different types of sensors and actuators for automation

LO3 Demonstrate design and implementation skills in programming PLC-based devices

LO4 Investigate the PROFINET standard and PROFINET operations and data analysis techniques.

Essential Content

LO1 Explore computer control in a feedback configuration

Types of control systems:

Industrial control systems

Continuous-time and discrete control

Types of controllers – continuous, discrete and logical

Applications of different types control systems in chosen occupation/sector (e.g., space, aeronautical, mechanical, manufacturing etc.).

Control configurations:

Open-loop systems

Closed-loop systems

Feedback, feedforward and cascade loops.

Control-loop elements:

Essential components in a control loop

Sensors and actuators – definition and examples

Data acquisition, roles of analogue-to-digital converter (ADC) and digital-to-analogue converter (DAC).

LO2 Examine different types of sensors and actuators for automation

Overview of measurement concepts:

Physical process variables: static and dynamic characteristics

Signals and noise in measurements.

Sensors for automation:

Measurement of physical quantities: typical sensors to measure temperature, pressure, flow, speed, position, and so on

Concepts of range, calibration, precision, reliability, limitations and appropriate use, and so on.

Actuators for automation:

Common actuators, characteristics and uses – valves, servomotors, and so on; control and safety concepts.

LO3 **Demonstrate design and implementation skills in programming PLC-based devices**

Programmable logic controllers (PLCs):

Architecture, operation, scan cycle, inputs and outputs

CPU, input and output modules, addressing convention

Examples of industrial application (e.g. satellite and microwave transmission, avionics systems for remote sensing, geophysical multisensor system, microsensors, electronic and optical actuation, bespoke PLC network products).

Programming for PLCs:

Programming using IEC 61131-3 standard languages such as ladder diagrams, function block diagrams, continuous function charts, structured text and sequential function charts

Project configuration, program organisation units (POUs), tasks

Application development using software environments; for example, human–machine interface (HMI) design using CODESYS and Siemens S7 PLCs

Network automation applications and related tools and platforms.

Skills and competencies:

Industrial computer control, automation, Industry 4.0 and beyond

Integration of automation and digital systems, and impact on organisations.

LO4 **Investigate the PROFINET standard and PROFINET operations and data analysis techniques.**

Industrial communication networks:

PROFINET, Ethernet IP, Modbus, IO Link, EtherCAT and other equivalent options

Overview of operation and maintenance: types of network maintenance, monitoring and diagnostics; evaluation and implementation of maintenance procedures; troubleshooting methodologies, tools and techniques for networks and IT infrastructure; workforce roles such as engineering technician, network engineer, systems engineer, and relevant competencies; occupational standards to meet sector demands).

Overview of PROFINET systems:

Requirements of real-time control networks

Network topologies (e.g., bus, ring, start, tree, mesh, and hybrid) used in PROFINET networks

The PROFINET standard

Application areas for PROFINET networks (including organisational context, PROFINET Network Engineer roles and occupational relevance, CPD).

Design and implementation of PROFINET systems:

PROFINET system design, protocols and principles of operation

PROFINET installation, troubleshooting (e.g., isolate, repair and escalate faults based on data) and maintenance in the context of Industry 4.0

Use of appropriate software and hardware tools; for example, ProfiTrace, Wireshark

Use of cloud-based systems for maintenance and analytics.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore computer control in a feedback configuration		
P1 Explore control configurations in an industrial context. **P2** Explain the function and use of the elements in a control loop.	**M1** Examine how the nature of signals (discrete, continuous, logical, quantitative) influences the selection of sensors and actuators, and the implications of DACs and ADCs in controller implementation.	**D1** Critically justify the selection of all elements in a digital control loop with reference to physical variables; for example, in a motion control system.
LO2 Examine different types of sensors and actuators for automation		
P3 Explain static and dynamic characteristics of sensors and actuators. **P4** Examine appropriate sensors and actuators for a practical system in a chosen application area.	**M2** Assess the effect of noise and ways of minimising its effects on measurements.	**D2** Analyse reliability and safety concepts associated with sensors and actuators.
LO3 Demonstrate design and implementation skills in programming PLC-based devices		
P5 Explain the architecture and operation of PLCs. **P6** Implement control programs using at least one IEC 61131-3 language; for example, combinational logic or ladder diagrams.	**M3** Demonstrate key programming skills in using more than one IEC 61131-3 language to produce automated control systems; for example, a conveyor operation.	**D3** Critically compare the relative merits of IEC 61131-3 programming languages in terms of application requirements; for example, batch operation versus continuous operation, human–machine interface (HMI) design.
LO4 Investigate the PROFINET standard and PROFINET operations and data analysis techniques.		
P7 Analyse the real-time features and general architecture of a PROFINET network. **P8** Investigate features of devices and switches in a PROFINET network with reference to applications.	**M4** Demonstrate skills in configuring and interpreting data frames in a typical PROFINET network. **M5** Review the relevance of the above skills in occupations linked to PROFINET usage.	**D4** Critically evaluate the protocols used in PROFINET networks with respect to topologies, configuration, commissioning, and standards.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Groover, M.P. (2020) Automation, Production Systems, and Computer-Integrated Manufacturing. 5th Ed. Addison Wesley.

Love, J. (2007) Process Automation Handbook: A Guide to Theory and Practice. Springer-Verlag.

Popp, M. (2015) *Industrial communication with PROFINET*. PROFIBUS Nutzerorganisation e.V. (PNO).

Powell, J. and Vandelinde, H. (2015) *Catching the Process Fieldbus: An introduction to PROFIBUS and PROFINET*. 2nd Ed. Siemens Milltronics Process Instruments.

Websites

http://www.profibus.com	PROFIBUS & PROFINET International (PI) (General reference)
http://www.profibusgroup.com	PROFIBUS.PROFINET United Kingdom 'All about PROFIBUS, PROFINET, IO-Link and omlox in the UK' (General reference)
http://www.profinews.com	PROFINEWS 'PROFINET, PROFIBUS, IO-Link, and omlox news from around the world' (General reference)
http://www.automation.com	Automation.com 'A subsidiary of the International Society of Automation' (General reference)
http://www.controleng.com	Control Engineering 'Control Engineering Magazine' (General reference)
http://www.controlglobal.com	Control (General reference)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Control Engineering Practice. ISSN: 0967-0661.

IET Control Theory and Applications. ISSN: 1751-8644.

Links

This unit links to the following related units:

Unit 4065: Internet and Network Technologies

Unit 4066: Data and Information

Unit 4067: Digital Devices and Systems

Unit 5049: Data Networks, Services and Security.

Unit 5049: Data Networks, Services and Security

Unit Code: K/650/2991

Level: 5

Credits: 15

Introduction

Computer networks enable communication both locally and cross-border and are the building blocks for personal and business interactions, offering people by far the most flexible means to socialise online, stream multimedia, shop for goods including groceries, and pay their bills, while giving businesses cost-effective solutions by which to share resources and sell products. In simple terms, computer networks are all about communication and sharing. The Internet is a complex network of networks and access to it has, over time, evolved into a fundamental human right. However, cybersecurity threats are real, with examples including but not limited to denial-of-service (DoS), identity theft and online harassment. To improve efficiency and be able to interact online securely and ethically, services delivered through this growing and interconnected environment must be regulated and well-designed to mitigate against cybersecurity risks and hazards.

This unit introduces students to the architecture and classification of the protocols of TCP/IP (Transmission Control Protocol/Internet Protocol) needed to design, deploy and manage a variety of computer networks in support of organisational requirements. Students will analyse the different types of networking technologies needed to secure data transmission for services both locally and over the Internet. The unit will also give students experience of working within a context of organisational values when assessing the ethical challenges and security risks involved in network design and deployment.

On successful completion of this unit, students will be able to explain the fundamental principles, architecture and classification of Internet protocols. They will appreciate the advantages and limitations of various TCP/IP protocols in addressing complex problems. Furthermore, students will be able to discuss, design and deploy a network as a solution for a business use case, including a strategy for network management and monitoring, and will do this with an appreciation for ethical and cybersecurity hazards and threats as part of their work. Hence, this unit helps students to develop industry-led skills in analysis and interpretation that are crucial to the opportunity to progress to a range of roles within the sector. Examples of job titles associated with these roles include network engineer, network security engineer, network administrator and network architect.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Investigate the architecture and classification of the network protocols needed to design, deploy and manage various computer networks in support of organisational requirements

LO2 Examine the different types of networking technologies needed to secure data transmission for services locally and over the Internet

LO3 Design and deploy a network as a solution for a business use case, including a strategy for network management and monitoring

LO4 Optimise network performance to address the challenges of a hostile organisational environment, including ethical and cybersecurity hazards and threats.

Essential Content

LO1 **Investigate the architecture and classification of the network protocols needed to design, deploy and manage various computer networks in support of organisational requirements**

Computer network architecture and types:

Advantages and disadvantages of peer-to-peer and client/server networks

Network types including local area network (LAN), personal area network (PAN), metropolitan area network (MAN) and wide area network (WAN)

Layered architecture to divide the design into small pieces

Concepts and characteristics of routing and switching

Network/multi-network server integration, and cloud computing concepts, purpose, and trends.

Classification of network protocols with examples:

Open Systems Interconnection (OSI) and TCP/IP models

Physical layer: Ethernet (IEEE 802.3), Token Ring, RS-232, and so on

Data link layer: PPP, IEEE 802.2

Network layer: IP, ARP, ICMP

Transport layer: TCP, UDP

Application layer: NFS, NIS+, DNS, telnet, ftp, rlogin, rsh, rcp, RIP, RDISC, SNMP, vlan and others.

Best practice for network design:

To include: drawing up and discussing initial requirements; investing in the correct and best equipment for the business; developing a strategy for the future (10 years); planning a holistic approach to security from start to finish; knowing where to use copper vs fibre cabling; compliance with standards; planning for redundancy, resiliency and availability; inclusion of monitoring and management capabilities; out-of-band access; doing research; consideration for the environment and other ethical requirements (cooling, power, and so on).

LO2 **Examine the different types of networking technologies needed to secure data transmission for services locally and over the Internet**

Requirements for network security:

Privacy and confidentiality, integrity, authentication and non-repudiation.

Types of technologies to provide network security:

Firewalls, virtual private network (VPN), data loss prevention, intrusion detection and prevention systems, email security application, anti-virus and anti-malware software, network services, network segmentation, network access control, application security, behavioural analytics, mobile device security, security information and event management (SIEM), web security, wireless topologies, configurations and security.

Cryptography:

Secret-key cryptography (symmetric cryptography): Advanced Encryption Standard (AES) versus older algorithms such as Data Encryption Standard (DES)

Public-key cryptography (asymmetric cryptography): Error Correction Code (ECC) and Diffie–Hellman

Hash functions: message-digest algorithm (MD5), Secure Hash Algorithms (SHA-1, SHA-2 and SHA-3), Whirlpool, BLAKE2, BLAKE3

Digital signatures and digital certificates

Transport Layer Security (TLS), as the successor of the now-deprecated Secure Sockets Layer (SSL).

LO3 **Design and deploy a network as a solution for a business use case, including a strategy for network management and monitoring**

Network design:

Network design software, including generic diagram design; for example, SolarWinds Network Topology Mapper, computer-aided design and engineering (CADE), Microsoft Visio, Edraw, Network Notepad

Network design methodologies, for example, Cisco’s Prepare, Plan, Design, Implement, Operate, and Optimize (PPDIOO) methodology

Network design with reference to service-level agreements (SLAs) and their application to delivering network engineering activities in line with contractual obligations and customer service.

Network management and monitoring:

Scalability, security vs performance, and cost

Plan for a network management protocol, for example, Simple Network Management Protocol (SNMP)

Developing a network management strategy; for example, objectives, required software capability, compliance for agents in the network

Tools/software; for example, Pandora Flexible Monitoring System (FMS), Observium Community, Cacti, Icinga, LibreNMS, LogRhythm NetMon Freemium, Checkmk Raw Edition, EventSentry Light, SolarWinds Network Performance Monitor, and Zabbix.

LO4 **Optimise network performance to address the challenges of a hostile organisational environment, including ethical and cybersecurity hazards and threats.**

Optimising network performance:

Relevant parameters, for example, Transmission Control Protocol (TCP) window size and latency

Methods, for example, caching data, removal of redundant data, quality of service (QoS), grouping multiple data requests, compressing data, buffering

Tools/software examples: Cisco WAN optimization tools, Riverbed SteelHead SD appliance, machine learning (ML)

Capabilities needed: software that can monitor network performance, traffic, configuration, applications, and storage, and has virtualisation built-in

Network and IT infrastructures: Causes and consequences of failures; tools and techniques to gather information to troubleshoot issues and isolate, repair or escalate faults

Troubleshooting methodologies for network and IT infrastructure.

Ethical and legal challenges for network design:

Examples include invisible control, limited access to resources, surveillance of activities, quality of service for users, discrimination and bias, privacy issues, unethical accounting

Compliance with data protection laws; for example, General Data Protection Regulation (GDPR), Computer Misuse Act 1990.

Cybersecurity threats and hazards:

A holistic approach to network security, for example, types of security threats to networks and IT infrastructure assets; maintain security and performance against known and standard threats; layered security and defence-in-depth strategy

Security information and event management (SIEM) tools; for example, Apache Metron, OSSEC and MozDef

Malware, denial-of-service (DoS)/distributed denial-of-service (DDoS) attack, insider threats, man-in-the-middle (MITM) attacks, phishing, Structured Query Language (SQL) injection, password attacks, contested ownership of data, misuse of personal data, problems of control and use of data and systems, lack of accuracy of non-individual recommendations, poor problem/solution alignment, cost, unexpected behaviour once deployed, lack of strategy and experience, third-party risks

Optimising network performance to support business continuity and disaster recovery using latest implementation techniques.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Investigate the architecture and classification of the network protocols needed to design, deploy and manage various computer networks in support of organisational requirements</td><td rowspan="4">LO1 and LO2
D1 Critique the impact of implementing TCP/IP protocols on the design and management of different types of secure computer networks in response to real-life organisational requirements</td></tr>
<tr><td>P1 Explain the architecture and classification of Internet protocols.
P2 Discuss the advantages and limitations of various TCP/IP protocols in addressing complex problems.</td><td>M1 Demonstrate examples of best practice to design and manage local computer networks to solve complex problems, both locally and across the Internet.</td></tr>
<tr><td colspan="2">LO2 Examine the different types of networking technologies needed to secure data transmission for services locally and over the Internet</td></tr>
<tr><td>P3 Explain the fundamental approaches to securing computer networks.
P4 Discuss the advantages and limitations of various secure protocols.</td><td>M2 Demonstrate how different secure network protocols solve complex cybersecurity challenges.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Design and deploy a network as a solution for a business use case, including a strategy for network management and monitoring		**LO3 and LO4**
P5 Design a network to address a real-world problem. **P6** Apply network management and monitoring capabilities.	**M3** Evaluate the performance and security of a network to solve a real-world problem scenario.	**D2** Evaluate approaches to optimise computer networks to manage the changing landscape of a hostile organisational environment, including ethical and cybersecurity hazards and threats
LO4 Optimise network performance to address the challenges of a hostile organisational environment, including ethical and cybersecurity hazards and threats.		
P7 Explain the methods for optimising the performance of computer networks. **P8** Review ethical and security hazards and threats associated with the development and running of a computer network.	**M4** Use appropriate methods to optimise a network with consideration of performance, and ethical and cybersecurity risks to both users and organisations.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Gupta, B.B., Perez, G.M., Agrawal, D.P. and Gupta, D. (2020). *Handbook of Computer Networks and Cyber Security: Principles and Paradigms*. Springer.

Montasari, R., Jahankhani, H., Al-Khateeb, H. (Eds.) (2021) *Challenges in the IoT and Smart Environments: A Practitioners' Guide to Security, Ethics and Criminal Threats*. Springer.

Stallings, W. (2017) *Network Security Essentials: Applications and Standards*. 6th ed. Pearson.

Websites

http://www.javatpoint.com	JavaTpoint 'Computer Network Tutorial' (General reference)
study-ccna.com	Study-CCNA.com 'Free CCNA Tutorials. Study CCNA for free!' (General reference)
ulfheim.net	Aiken & Driscoll 'The Illustrated TLS Connection' (Tutorial)
vpnoverview.com	VPNOverview.com 'VPN Explained: How Does It Work? Why Would You Use It?' (Article)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Dai, B., Xu, G., Huang, B., Qin, P. and Xu, Y. (2017) Enabling network innovation in data center networks with software defined networking: A survey. *Journal of Network and Computer Applications*, 94, 33–49.

Goswami, B. and Asadollahi, S.S. (2018) Enhancement of LAN infrastructure performance for data center in presence of network security. In Lobiyal, D.K., Mansotra, V. & Singh, U. (Eds), *Next-Generation Networks: Proceedings of CSI-2015* (pp. 419–432). Springer.

Ma, B., Guo, W. and Zhang, J. (2020) A survey of online data-driven proactive 5G network optimisation using machine learning. *IEEE Access*, 8, 35606–35637.

Malik, A. and de Fréin, R. (2020) SLA-aware routing strategy for multi-tenant software-defined networks. In *2020 IEEE Symposium on Computers and Communications (ISCC)* (pp. 1–7). IEEE.

Swagatika, S. and Rath, A.K. (2019) SLA-aware task allocation with resource optimisation on cloud environment. *International Journal of Communication Networks and Distributed Systems*, 22(2), 150–169.

Links

This unit links to the following related units:

Unit 4061: Programming for Engineers

Unit 4065: Internet and Network Technologies

Unit 4066: Data and Information

Unit 5050: Machine Learning Systems and Programming.

Unit 5050: Machine Learning Systems and Programming

Unit Code: L/650/2992

Level: 5

Credits: 15

Introduction

Machine learning (ML) is a field of artificial intelligence (AI)-related research that enables computer systems to respond to events without being explicitly programmed. There are several advantages to the use of ML. For example, its models can be used to support automation and reduce workload and delays within the supply chain. ML can be applied to a wide range of applications and is effectively transforming the computing industry. We rely on ML algorithms to improve the performance of both software and hardware in areas such as healthcare, manufacturing, service industries and information services. Furthermore, ML is proving to be reliable for data handling jobs that traditional systems cannot process owing to complexity, type or volume. While ML is being used to make devices smarter (e.g. self-driving cars), it is also being used to offer direct support to people by means of personal aid devices, and to provide more user-centric education to students to help them focus better on tasks and locate relevant information. However, ML is not without challenges, and as a community we must still study and apply programming design principles to reduce errors and bias in ML algorithms and to achieve better performance with shorter training times.

The unit introduces students to ML through best coding practices, programming languages that support object-oriented programming (OOP), such as Python, and OOP design principles. Students will learn to analyse different ML approaches and algorithms and critique their impact while using them to solve real-life problems. They will discover the most effective ML techniques, including practical know-how. The unit will also give students experience of working within a context of organisational values when assessing the ethical challenges and security risks involved in machine learning. Other underpinning topics covered include ML approaches and algorithms (e.g. linear regression, decision tree, and *k*-nearest neighbours), measures of success, models, ethical challenges, legal issues, and security risks.

On successful completion of this unit, students will be able to explain the fundamental principles of OOP and discuss best coding practices for its use in developing ML solutions. Furthermore, students will be able to demonstrate how different ML approaches and algorithms can be used together in software development to solve complex problems. Students will fully appreciate the ethical, legal and security issues and risks for both users and organisations when deploying ML to make automated decisions. Thus, this unit helps students to develop industry-led skills in analysis and interpretation that are crucial to the opportunity to progress to a range of roles within the sector. Examples of job titles associated with these roles include ML engineer, data scientist, and software developer.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Investigate and articulate the best coding practices and object-oriented programming design principles involved in developing machine learning applications

LO2 Analyse different machine learning approaches and algorithms

LO3 Apply machine learning to solve real-world problems using object-oriented programming

LO4 Assess the ethical challenges and security risks of machine learning within the context of organisational values.

Essential Content

LO1 **Investigate and articulate the best coding practices and object-oriented programming design principles involved in developing machine learning applications**

Overview of object-oriented (OO) approach:

Principles (e.g. encapsulation, abstraction, polymorphism and inheritance)

Concepts (i.e. object, class, attributes, methods, instantiation, etc.)

Object-oriented analysis and design (OOAD)

Unified Modeling Language (UML) for OO: key elements, notation and diagrams.

Best coding practices:

Writing clean code and developing tests

Programming principles, for example, don't repeat yourself (DRY), encapsulate what changes, open–closed design principle, single responsibility principle (SRP), dependency inversion principle and dependency injection, favour composition over inheritance, Liskov substitution principle (LSP), interface segregation principle (ISP), program for interface and not implementation, delegation principles.

Machine learning best practices:

Establish a business problem statement, finalise a specific, measurable, achievable, realistic and timely (SMART) objective, utilise historical data from legacy systems, adopt a simple metric for the first objective to address

Define the inputs to and outputs from the system and the latency requirements

Develop the infrastructure independently of the developed model

Develop sanity checks to validate machine learning models

Data best practices; for example, to cover data quality and transformation, data quantity, data control

Model best practices; for example, using checkpoints, performance metrics.

Machine learning applications:

To include image recognition, self-driving cars, product recommendations, traffic predictions, the use of tinyML for microcontrollers, and so on.

LO2 **Analyse different machine learning approaches and algorithms**

Machine learning approaches:

To include supervised learning, semi-supervised learning, unsupervised learning, reinforcement learning, self-learning, feature learning, anomaly detection, and so on.

Machine learning algorithms:

Linear regression, logistic regression, decision trees, *k*-nearest neighbours (*k*-NN), support-vector machine (SVM), naïve Bayes, *k*-means clustering, random forests, dimensionality reduction algorithms, gradient boosting and Ada(ptive)Boost.

Machine learning advantages:

To include continuous improvement, automation, pattern recognition, filters, wide application range, and so on.

Machine learning challenges:

For example, can be time-consuming, algorithm selection is often complex, error rates can be high, problem of underfitting/overfitting in relation to the training data.

LO3 **Apply machine learning to solve real-world problems using object-oriented programming**

Measures of success for machine learning:

Business impact (including stakeholder engagement and expectations, and interpretation and implementation of requirements from stakeholders), model accuracy and other engineering matrices

Evaluation matrices; for example, classification accuracy, logarithmic loss, confusion matrix, area under curve, F1 score, mean absolute error, mean squared error.

Machine learning models:

Differentiate between machine learning models and algorithms: algorithms are procedures that are implemented in code whilst models are the output and are comprised of model data and a prediction algorithm

Examples of algorithms include linear regression, which results in a model comprised of a vector of coefficients with specific values, and decision tree, which results in a model comprised of a tree of if-then statements with specific values

Model development activities; for example, selection, processing, acceleration, automating, tuning, integration, visualising, and enabling.

Object-oriented programming languages:

Significant languages that support OOP, including C#, Java, C++, Python, R, PHP, Visual Basic.NET, JavaScript, Ruby, Perl, SIMSCRIPT, Object Pascal and Objective-C.

LO4 **Assess the ethical challenges and security risks of machine learning within the context of organisational values.**

Organisational values:

Defining organisational values

How organisational values influence the core principles a company abides by

How organisational values inspire employees' best efforts and also constrain their actions

Examples of company values: loyalty, honesty, trust, ingenuity, accountability, simplicity, respect, and so on

Appreciating the strategic benefits of organisational values in controlling inappropriate behaviour, strengthening value propositions, and enhancing employment policies; long-term benefits in relation to an organisation's ethical character.

Ethical challenges of machine learning:

Algorithmic bias, job loss and wealth inequality, violation of fundamental human rights in the supply chain, negative impact on vulnerable groups, negative impact on democracy, unequal power relations, and so on

Frameworks for ethical use of machine learning

Human-centred machine learning

Requirements of Responsible AI: explainability, fairness, robustness, privacy, transparency, and so on.

Legal risks related to machine learning:

While bias is an ethical challenge, it can also cause discrimination on the basis of protected characteristics (age, disability, race, etc.) which is illegal in many jurisdictions, including the UK

Using machine learning to support illegal operations such as unauthorised access and analysis of sensitive data

The impact of machine learning on the justice system.

Other security risks related to machine learning:

Contested ownership of data, misuse of personal data, problems of control and use of data and systems, lack of accuracy of non-individual recommendations, poor problem/solution alignment, cost, unexpected behaviour once deployed, lack of strategy, lack of experience, third-party risks, impact of security risks on networks and IT infrastructure assets, and so on.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate and articulate the best coding practices and object-oriented programming (OOP) design principles involved in developing machine learning applications		**LO1 and LO2**
P1 Explain the fundamental principles of OOP. **P2** Investigate best coding practices to develop machine learning solutions using OOP.	**M1** Demonstrate examples of best coding practices for machine learning while adhering to OOP design principles.	**D1** Evaluate the impact of implementing machine learning algorithms to solve real-life problems using best coding practices and adhering to OOP design principles.
LO2 Analyse different machine learning approaches and algorithms		
P3 Analyse the fundamental machine learning approaches for developing a learning system. **P4** Discuss the advantages and limitations of machine learning algorithms in solving complex problems.	**M2** Demonstrate how different machine learning approaches and algorithms work together in software development to solve complex problems.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Apply machine learning to solve real-world problems using object-oriented programming</td><td rowspan="4">LO3 and LO4

D2 Evaluate new machine learning models using OOP, while appraising the benefits, ethical challenges and security risks for an organisation.</td></tr>
<tr><td>P5 Design measures of success for new machine learning models in addressing a real-world problem.

P6 Apply machine learning algorithms to develop a working model using OOP.</td><td>M3 Develop new machine learning models using OOP to solve a real-world problem or a given scenario.</td></tr>
<tr><td colspan="2">LO4 Assess the ethical challenges and security risks of machine learning within the context of organisational values.</td></tr>
<tr><td>P7 Investigate the ethical considerations for the use of machine learning by businesses.

P8 Review the security risks associated with machine learning for business decision-making.</td><td>M4 Determine the ethical, legal and security risks to both users and organisations when deploying machine learning to make automated (business) decisions.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

López de Prado, M. (2018) *Advances in Financial Machine Learning*. John Wiley & Sons.

Mohri, M., Rostamizadeh, A. and Talwalkar, A. (2018) *Foundations of Machine Learning*. MIT Press.

Palmer, A. and Hartley, B. (2011) *The Business Environment*. 7th Ed. McGraw Hill.

Sarkar, D., Bali, R. and Sharma, T. (2018) *Practical Machine Learning with Python. A Problem-Solver's Guide to Building Real-World Intelligent Systems*. Apress.

Websites

dziganto.github.io	Standard Deviations (David Ziganto) 'Understanding Object-Oriented Programming Through Machine Learning' (Article)
http://www.toptal.com/developers/blog	Toptal Engineering Blog 'An Introduction to Machine Learning Theory and Its Applications: A Visual Tutorial with Examples (Nick McCrea)' (Tutorial)
http://www.mygreatlearning.com/blog	Great Learning Blog 'Machine Learning Tutorial For Complete Beginners | Learn Machine Learning with Python' (Tutorial)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Binkhonain, M. and Zhao, L. (2019) A review of machine learning algorithms for identification and classification of non-functional requirements. *Expert Systems with Applications: X*, 1, 100001.

Creps, M.J., Jr. (2018) A Supervised Machine Learning Approach Using Object-Oriented Programming Principles (Doctoral dissertation, University of Toledo).

Latif, J., Xiao, C., Imran, A. and Tu, S. (2019) Medical imaging using machine learning and deep learning algorithms: A review. In *2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)* (pp. 1–5). IEEE.

Nah, K.-O. and Lee, S.-M. (2016) Actualizing children's participation in the development of outdoor play areas at an early childhood institution. *Action Research*, 14(3), 335–351.

Ray, S. (2019) A quick review of machine learning algorithms. In 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon) (pp. 35–39). IEEE.

Yavanoglu, O. and Aydos, M. (2017) A review on cyber security datasets for machine learning algorithms. In *2017 IEEE International Conference on Big Data (Big Data)* (pp. 2186–2193). IEEE.

Links

This unit links to the following related units:

Unit 4061: Programming for Engineers

Unit 4065: Internet and Network Technologies

Unit 4066: Data and Information

Unit 5049: Data Networks, Services and Security.

Unit 5051: Heating, Ventilation and Air Conditioning (HVAC)

Unit code H/615/1524

Unit level 5

Credit value 15

Introduction

The buildings we use in everyday life to live, work, study and socialise are becoming increasingly more complex in their design. As well as being subject to more stringent environmental emission targets, within these buildings the heating, ventilation and air conditioning (HVAC) systems play a vital role in maintaining the comfort of the occupants within the built environment.

This unit will introduce students to some of the most important HVAC systems and their supporting elements, and the underpinning science that is currently used in many different buildings around the world.

Subjects covered include: ventilation rates, systems, legislation, strategies and associated equipment. Also explored are topics such as air conditioning systems, cooling loads, psychrometric principles and processes, heating systems, fuels, combustion processes, boiler efficiency calculations and Building Management Systems (BMS).

On successful completion of this unit students will be able to explain the fundamental principles of HVAC systems and discuss the operational advantages of using BMS for maintaining the careful balance between ergonomic climate control and maximum economic efficiency.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explain the operating principles of non-domestic ventilation systems

LO2 Explore the range of air conditioning systems

LO3 Investigate the operational characteristics of non-domestic heating systems

LO4 Describe the role Building Management Systems (BMS) have in controlling and monitoring HVAC systems.

Essential Content

LO1 **Explain the operating principles of non-domestic ventilation systems**

Ventilation systems:

Ventilation requirements: approved documents, requirements for occupants or processes

Ventilation strategies: local or centralised systems, natural ventilation, extract only, supply only and balanced systems

Ventilation system components and typical system layouts.

Ventilation rates:

Calculation of ventilation rates, supply for occupants or processes, supply to achieve required room air change rate

Mass and volumetric flow rates to maintain design room conditions.

Fans:

Fan types and operational characteristics

Fan selection and Fan Laws.

LO2 **Explore the range of air conditioning systems**

Air conditioning systems:

Air conditioning requirements: requirement for comfort cooling or close control

Air conditioning strategies: types of air conditioning plant.

Cooling loads:

Estimation of heat gains and cooling loads

Factors affecting the cooling load requirements, building/room use, shading, building construction and orientation, internal heat gains.

Psychrometrics:

Psychrometric principles: psychrometric terms and properties

Plotting psychrometric processes using charts

Use of psychrometric charts to determine cooling coil, heater battery, frost coil and humidifier duties.

LO3 **Investigate the operational characteristics of non-domestic heating systems**

Heating systems:

Heating requirements: approved documents, occupant's comfort

Heat loss calculations: heat losses though a structure, U values and there use in calculating heating load requirements

Heating strategies: local or centralised systems

Heating system components and typical system layouts.

Fuels:

Properties and characteristics of common solid, liquid and gaseous fuels.

Combustion:

Combustion principles

Products of complete and incomplete combustion and their implications

Minimum air requirements for stoichiometric combustion

Causes of incomplete combustion.

Boiler efficiency:

Boiler efficiency calculations.

LO4 **Describe the role Building Management Systems (BMS) have in controlling and monitoring HVAC systems.**

Requirement of the BMS:

Client/end user requirements and operational needs, energy efficiency concerns.

Function of a BMS:

Systems controlled by BMS: heating, lighting, ventilation, air conditioning, security/access

Energy monitoring and reporting.

BMS hardware:

Types of BMS hardware available, advantages and disadvantages, performance and cost. Controlling software, remote access and control.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the operating principles of non-domestic ventilation systems		**LO1 and LO2**
P1 Explain and compare two alternative ventilation strategies for a non-domestic building and recommend the most suitable. **P2** Using the information from P1, calculate the ventilation requirements for the rooms in a non-domestic building.	**M1** Discuss the types of fans used in non-domestic ventilation systems and analyse their characteristics.	**D1** Evaluate and compare a number of passive and active methods used to help cool buildings giving suitable examples.
LO2 Explore the range of air conditioning systems		
P3 Explain the requirement for air conditioning in a variety of non-domestic buildings. **P4** Estimate the cooling load requirements for rooms in non-domestic buildings using a recognised 'rule of thumb' method.	**M2** Analyse the factors affecting the cooling loads in buildings.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Investigate the operational characteristics of non-domestic heating systems</td><td rowspan="4">LO3 and LO4

D2 Calculate the minimum air requirements for a given fuel and distinguish between complete and incomplete combustion, predicting the possible consequences of incomplete combustion.</td></tr>
<tr><td>P5 Explain and compare two alternative heating strategies for a non-domestic building and recommend the most suitable.

P6 Estimate the heating load requirements for rooms in non-domestic buildings using a recognised ‘rule of thumb’ method.</td><td>M3 Discuss the combustion properties of common fuels used in non-domestic heating systems.</td></tr>
<tr><td colspan="2">LO4 Describe the role Building Management Systems (BMS) have in controlling and monitoring HVAC systems.</td></tr>
<tr><td>P7 Describe the requirements of a building management system in non-domestic buildings.

P8 Describe the functions performed by a building management system in a non-domestic building.</td><td>M4 Evaluate the advantages of a building fitted with a full Building Management System.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Chadderton, D. (2013) *Building Services Engineering*. 6th Ed. Abingdon: Routledge.

Cibse (2016) *Guide B: Heating, Ventilating, Air Conditioning and Refrigeration*. London.

Cibse (2016) *Guide F: Energy Efficiency in Buildings*. London.

Cibse. (2009) *CIBSE Guide H: Building control systems*. CIBSE, London.

Hall F. and GREENO R. (2023) *Building Services Handbook*. 10th Ed. Routledge.

Porges F. (2020) *HVAC Engineer's Handbook*.11th Ed. Blackwells.

Unit 5052: Space Communications

Unit Code: R/650/3370

Level: 5

Credits: 15

Introduction

Satellites have transformed the way we live our lives, and our understanding of the Earth and the Universe. Whatever their purpose – whether being used to study climate, guide aircraft across the oceans, provide internet access to remote locations, or explore the surface of Mars – all spacecraft need to communicate with users on the Earth. That is the role of the communications subsystem.

The aim of this unit is to provide students with insight into the engineering design and operation of communications subsystems in the specific context of space missions, and the scientific principles that enable the encoding and transfer of information and instructions between Earth and the spacecraft.

Among the topics taught in this unit are: waves and oscillations; basic radio theory; analogue-to-digital conversion; encoding of data on radio waves; antennas and gain; filters and amplification; interference, noise and attenuation; telemetry bandwidth and data rate; compression and error correction; the role of the ground station in space telecommunication. While the emphasis of the unit is on radio frequency communications, optical communication methods are also considered.

On successful completion of this unit, students will be able to describe how information is prepared for transmission to/from a spacecraft, in different parts of space such as deep space, and the role of each piece of equipment in the communications chain in ensuring that data is received correctly at its intended destination. Students will be able to apply mathematical principles and engineering knowledge to estimate key performance requirements for a system, including power, antenna size and signal strength for a communications link between a spacecraft and the ground, allowing them to design a simple communications network for satellites.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Explore the use of radio waves to transmit information

LO2 Investigate the components of a space communications subsystem

LO3 Assess applications of space telecommunications

LO4 Examine design aspects of a communications architecture for a space project.

Essential Content

LO1 **Explore the use of radio waves to transmit information**

Waves and oscillations:

Characteristics: frequency, wavelength, amplitude, polarization and phase

Mathematical concepts and models, including wave equations, decibels, radio waves and power calculation.

Processes and methods of encoding information:

Carriers, baseband and bandwidth

Analogue-to-digital conversion (ADC) and binary representation of data

Modulation and demodulation

Data rates and volumes; Data handling

Compression and error correction

Efficient transmission and encoding of information between the ground and a satellite/spacecraft.

LO2 **Investigate the components of a space communications subsystem**

Components of a communications chain:

Transmitters and receivers

Antennas

Mixing and up/down converters

Diplexers

Demodulators and decoders

Digital signal processors

Electronically steered antennas and beamforming

Amplifiers

Hardware and software-defined radios (SDR).

Space and ground segments:

Function of the ground segment

Hubs and terminals

Tracking, telemetry and command (TT&C).

Optical communications:

General principles and requirements of optical communications systems

Optical medium, materials and usage

Advantages and disadvantages of optical communications compared to radio frequency (RF) systems

Case studies: ground–space–ground communications systems with mission-specific performance requirements.

LO3 **Assess applications of space telecommunications**

Practical applications of space communications subsystems:

Unidirectional and bidirectional links

Relay systems

Intersatellite links (RF and optical)

Satellite broadcasting

Principles of position, navigation and timing (PNT)

Broadband satellite networks

Mobile communications

Radar systems.

Regulation of space telecommunications:

The International Telecommunication Union (ITU)

Radiocommunication service types and frequency allocation

Laws and licensing.

LO4 **Examine design aspects of a communications architecture for a space project.**

The communications link budget:

Identification of user requirements

Application of radio frequency (RF) link budget calculations; determine a communications architecture (power, antenna size and gain); estimate the signal-to-noise ratios obtained over ground–satellite and satellite–ground communications networks with known design parameters to meet user requirements.

Communications link opportunities:

Ground station locations and visibility from orbit

Relative motion of satellite and ground station

Estimation of contact duration for individual space–ground contact opportunities

Deep space communications and comparison to communications with low Earth orbit (LEO) satellites (including uplink and downlink delays, interaction of radio and optical signals with atmospheres, etc.).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore the use of radio waves to transmit information		**LO1 and LO2**
P1 Discuss the defining characteristics of radio waves and their mathematical description. **P2** Present methods for conveying information by encoding data onto radio waves.	**M1** Evaluate the processes that modify a radio signal in its journey between the ground and a satellite.	**D1** Construct a mathematical model to describe the transmission of radio frequency energy between the ground and a spacecraft.
LO2 Investigate the components of a space communications subsystem		
P3 Investigate the role of the principal mechanical and electronic elements in a communications chain to facilitate the transmission of information across free space. **P4** Summarise the advantages and technical requirements of optical methods for communication between spacecraft and the ground.	**M2** Analyse the primary user requirements which influence the design of a bidirectional (ground-to-space-to-ground) communications system.	

Pass	Merit	Distinction
LO3 Assess applications of space telecommunications		**LO3 and LO4**
P5 Assess the range of functions and services enabled by spacecraft communications systems. **P6** Summarize the communications regulation requirements which must be met by spacecraft operators.	**M3** Investigate the principal distinguishing characteristics of communications subsystems designed for specific applications.	**D2** Justify the design of a telecommunication subsystem architecture that meets the objectives of a given application.
LO4 Examine design aspects of a communications architecture for a space project		
P7 Determine the principal performance and design parameters for a radio communications link architecture. **P8** Analyse the geometrical considerations that determine the number and duration of communications opportunities between a spacecraft and the ground station(s).	**M4** Evaluate the principal design parameters for a bidirectional (ground space-to-ground) communications link that meets user requirements for carrier-to-noise ratio, spacecraft transmitter power and antenna dimensions.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Bhargava, V.K., Haccoun, D., Matyas, R. and Nuspi, P.P. (1981) *Digital Communications by Satellite*. Wiley.

Evans, B.G. (2008) *Satellite Communication Systems.* 3rd Ed. The Institution of Engineering and Technology (IET).

Fortescue, A., Swinerd, G. and Stark, J. (2011) *Spacecraft Systems Engineering.* 4th Ed. Wiley.

Morgan, W.L. and Gordon, G.D. (1989) *Communications Satellite Handbook*. Wiley.

Otung, I., Butash, T., Ikegami, T. (Eds.) (2021) *Advances in Communications Satellite Systems: Proceedings of the 37th International Communications Satellite Systems Conference (ICSSC-2019)*. The Institution of Engineering and Technology (IET).

Pelton, J. (2012) *Satellite Communications*. Springer.

Websites

http://www.nasa.gov/smallsat-institute/sst-soa/communications	NASA State-of-the-Art of Small Spacecraft Technology; Communications (General reference)
http://www.youtube.com/user/VideoFromSpace	VideoFromSpace 'Communicating With Deep Space – How It Works | Video' (Tutorial)
http://www.youtube.com/c/bbcearth	BBC Earth 'How Do Satellites Help Us Communicate? | Space on Earth | BBC Earth' (Tutorial)
artes.esa.int	The European Space Agency 'Telecom: ARTES 4.0 Programme' (General reference)

http://www.gov.uk/government/publications/an-evaluation-of-uk-funding-through-the-artes-programme	GOV.UK 'An evaluation of UK funding through the ARTES programme' (General reference)

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Radioelectronics and Communications Systems. ISSN: 0735-2727.

International Journal of Satellite Communications and Networking. ISSN: 1542-0973.

IEEE Transactions on Communications. ISSN: 1558-0857 (online).

IEEE Communications Society monthly magazines.

Links

This unit links to the following related units:

Unit 4087: Space Environment and Applications

Unit 4088: Space Technologies and Manufacturing

Unit 5053: Space Mission Design.

Unit 5053: Space Mission Design

Unit Code: T/650/3371

Level: 5

Credits: 15

Introduction

Space is a key part of many countries' strategies, and with this growth there will be a demand for people with specialist skills to take a set of user requirements and turn them into a full space mission. The design, manufacture and operation of spacecraft is a vitally important and highly sophisticated industry in which technicians, technologists, and engineers are at the heart.

The aim of this unit is to introduce students to the end-to-end process of designing a space mission to meet the requirements of a user. Among the topics taught in this unit are: mission duration and how design affects the life of a mission; end-of-life, de-orbit processes, and the impact on the Earth and space environment; the operational, functional and logistical constraints on a space mission; parametric design estimation for system design and performance; tolerances of materials used in space and the use of additive manufacturing in space components; how to develop a concept of operations (ConOps); how to plan for and respond to failures, faults and user error; correct mission documentation and project management for the space sector.

On successful completion of this unit, students will be able to apply scientific and engineering knowledge to design a full space mission to meet user requirements. They will have developed the key knowledge needed to identify improvements to mission performance through mathematical and modelling tools. Students will understand the impact of their choices on spacecraft design, testing, and mission duration, and will be able to communicate this in industry-standard technical documentation.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Analyse space mission user requirements

LO2 Calculate optimum mission design parameters

LO3 Develop a concept of operations

LO4 Produce documentation for an end-to-end preliminary design of a space mission.

Essential Content

LO1 **Analyse space mission user requirements**

Mission objectives:

Space mission statements and aims (e.g. Earth observation, atmospheric monitoring, communications, navigation, etc.)

Primary and secondary objectives

Identifying the most suitable orbit.

Space missions – past, present and future trends:

Overview of historic development of space systems; the hand-drafted/hand-calculated nature of the missions; scientific and technological advancements; current state (e.g. modelling, simulation and design software programs) and future trends

Space mission teams (roles, competencies, team leadership and management, continuous professional development (CPD) including upskilling/reskilling opportunities (e.g. latest digital knowledge and skills, sustainability).

Operational requirements and limits:

Interpreting customer requirements (e.g. functional, non-functional)

Mission duration (including redundancy, orbital influence, fuel budget, extended lifetime)

Survivability (including orbital influence, radiation hardening and its effect on electronic components)

Data (including user needs, level and place of processing, payload, quantity, and type of data transmission)

End-of-life and de-orbit processes.

Project requirements:

Cost of components, launch, and assembly, integration and testing (AIT) facilities

Scheduling and mission timeline (including procurement, technical readiness levels and launch window)

Legal and regulatory.

Functional spacecraft requirements:

Performance (including payload size, pointing budget, systems budgets)

Coverage (including orbital dynamics, number of satellites, constellations)

Responsiveness (including communications architecture, ground stations, processing delays, operations)

Work products such as requirements specification and preliminary design.

LO2 **Calculate optimum mission design parameters**

System modelling and simulation:

Parametric design estimates for subsystems design and performance (e.g. wet mass, dry mass, end-of-life power, launch-configuration volume)

Commonly used equations; modelling and simulation tools for finite element analysis, orbit and constellation modelling, and space environment and effects (e.g. NASTRAN, AGI Systems Tool Kit, NASA's GMAT).

Appropriate choice of components and materials:

Behaviour and tolerances of materials used in a space system

Survivability and reliability of components and materials in a space environment (including orbital influence, radiation hardening and its effect on electronic components)

Structural support of materials (e.g. ability to withstand gravitational forces and launch conditions).

Use of 3D printing and additive manufacturing:

Sustainability of materials and processes

Use of 3D printing and additive manufacturing in space components (e.g. rocket nozzles, fuel tanks, radio frequency (RF) filters and waveguides, mechanical brackets)

Benefits of 3D printing and additive manufacturing for space components (e.g. speed, reproducibility). Standards and compliance.

LO3 **Develop a concept of operations**

Overview of a concept of operations (ConOps):

Information that should be contained within a ConOps

Correct terminology, acronyms, sections, documents and formatting

Case studies from space agencies and private missions.

Overview and description of system:

High-level overview of the system, mission objectives

Interfaces and how the system will communicate with other systems (e.g. radio frequency, mechanical, electrical)

Modes of operation (e.g. testing mode, emergency mode)

Proposed capabilities (including tasks that the system must accomplish during its lifetime and during the decommissioning phase).

Physical and support environment:

Environment in which the system will perform (e.g. assembly, integration, testing, transportation, launch and operations)

Tolerances of the system in the space environment (including orbital influence, radiation hardening and the effect on electronic components)

Life-time support and monitoring of the system, software upgrades, and use of redundancy.

Operational scenarios and impacts:

System response to nominal and off-nominal conditions (e.g. failure, unexpected environmental conditions, operator error)

Impact of the system on the Earth and space environment during launch and end-of-life (e.g. space debris, deorbit, hazardous waste)

Contingency modes of operation.

LO4 **Produce documentation for an end-to-end preliminary design of a space mission.**

Mission documentation:

Summary of the mission objectives, user requirements, mission parameters, and ConOps

Preliminary design ideas

Evaluation of the mission (including whether the design meets the mission objectives, user and stakeholder requirements, operational requirements and functional requirements).

Project management:

Common project management tools

Product trees and work breakdown structures

Risk identification and assessment

Risk management policy.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Analyse space mission user requirements</td><td rowspan="4">LO1 and LO2

D1 Create a preliminary design of a space mission based on a given set of user requirements, including launch, orbit and end-of-life processes, making use of components that are compliant with the space environment.</td></tr>
<tr><td>P1 Analyse a range of spacecraft systems to meet a customer’s budget and user requirements.

P2 Discuss a range of end-of-life and de-orbit processes.</td><td>M1 Investigate the key operational requirements that limit the lifetime of a space mission and how mission duration lifetime might be extended.</td></tr>
<tr><td colspan="2">LO2 Calculate optimum mission design parameters</td></tr>
<tr><td>P3 Calculate the optimum orbit and constellation configuration for a chosen space mission.

P4 Discuss the key considerations in choosing appropriate materials for the components in a space system.</td><td>M2 Assess opportunities for design optimisation using additive manufacturing solutions.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Develop a concept of operations		**LO3 and LO4**
P5 Develop an illustrative diagram which indicates how the space system will communicate with ground stations as part of ConOps. **P6** Determine end-of-life procedures appropriate to the mission and evaluate their impact on the mission and the space and Earth environments.	**M3** Present contingency modes of operation for a range of off-nominal conditions that may affect the mission.	**D2** Produce updated documentation for an end-to-end preliminary design of a space mission to meet the needs of the user, including a concept of operations and breakdown of work.
LO4 Produce documentation for an end-to-end preliminary design of a space mission.		
P7 Produce a product tree for a space mission. **P8** Discuss the key risks that could delay a space mission and the risk management procedures used to address risks.	**P7** Produce a product tree for a space mission. **P8** Discuss the key risks that could delay a space mission and the risk management procedures used to address risks.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Fortescue, A., Swinerd, G. and Stark, J. (2011) *Spacecraft Systems Engineering.* 4th Ed. Wiley.

Wertz, W.J. and Larson, W.J. (Eds.) (1999) *Space Mission Analysis and Design*. 3rd Ed. Springer.

Websites

http://www.engineeringtoolbox.com	The Engineering ToolBox (General reference)
software.nasa.gov	NASA Technology Transfer Program: Software Catalog 'General Mission Analysis Tool (GMAT) Version R2018a (GSC-18094-1)' (Development tool)
http://www.nasa.gov/smallsat-institute/sst-soa/communications	NASA Small Spacecraft Virtual Institute 'Space Mission Design Tools' (General reference)
spaceflight.com	Spaceflight 'Mission Planning Guide' (PDF) (General reference)
cubesat.org	CubeSat '6U CubeSat Design Specification Rev 1.0' (General reference)
swe.ssa.esa.int/TECEES/spweather/Alpbach2002/	Proceedings of ASA Alpbach Summer School 2002 on Space Weather: Physics, Impacts and Predictions 'Basic Steps in Designing Space Missions (Richard Marsden)' (PDF) (Tutorial)

everyspec.com/ESA/	EverySpec.com 'ECSS-M-ST-10C (REV. 1), Space project management: Project planning and implementation (06-MAR-2009)' (General reference)
http://www.nasa.gov/seh/	NASA Systems Engineering Handbook 'Appendix S: Concept of Operations Annotated Outline' (General reference)
public.ccsds.org	Consultative Committee for Space Data Systems (CCSDS) (General reference)
http://www.space-track.org	Space-Track.org (Development tool)
celestrak.com	CelesTrak (for two-line elements) (Development tool)
http://www.esa.int/About_Us/ESOC	European Space Operations Centre (General reference)

Links

This unit links to the following related units:

Unit 4087: Space Environment and Applications

Unit 4088: Space Technologies and Manufacturing

Unit 5052: Space Communications.

Unit 5054: Net Zero Energy Technologies II: Infrastructure and Pathways

Unit Code: **Y/650/3372**

Level: **5**

Credits: **15**

Introduction

Immediate and deep greenhouse gas (GHG) emissions reduction across all sectors of the global economy is required to avoid the catastrophic impacts of human-made climate change and ecological breakdown. As the largest-emitting sector of the global economy (responsible for nearly three-quarters of total emissions), decarbonisation of the energy system is vital. Energy sector technologies will continue to be pivotal in addressing these net zero targets.

The aim of this unit is to build upon the content delivered in *Unit 4089: Net Zero Energy Technologies I: Systems and Demand* by developing students' understanding of the energy system infrastructure required for net zero, and how net zero pathways are constructed for whole energy systems.

On successful completion of this unit, students will understand the key changes to energy system infrastructure required for net zero, including energy distribution and use, and carbon capture and storage. Through development of critical appraisal, students will be able to evaluate the suitability of different technologies in different contexts. They will be able to analyse net zero pathways that are constructed for energy systems, including how the development of technology can interact with energy demand and social practice.

Learning Outcomes

By the end of this unit, a student will be able to:

LO1 Explore key changes to energy system infrastructure required for net zero

LO2 Evaluate the suitability of different energy system infrastructure for meeting net zero targets in given geographical and socio-economic contexts

LO3 Analyse how net zero pathways are constructed for energy systems in a variety of geographical and socio-economic contexts

LO4 Critically compare alternative net zero pathways for a given energy system.

Essential Content

LO1 **Explore key changes to energy system infrastructure required for net zero**

Electricity generation technologies – operating principles, merits, and drawbacks:

Renewable electricity generation technologies (wind, solar, ocean and tidal, bioenergy, hydro, geothermal)

Thermal electricity generation technologies (fossil fuels with carbon capture and storage, nuclear, bioenergy)

Life-cycle emissions assessments of electricity generation technologies; discussion of 'carbon cost-effectiveness' of technologies.

Fuels for net zero – properties, applications, merits and drawbacks:

Liquid fuel production (e.g. hydrogen production from electrolysis; ammonia production from the Haber–Bosch process; synthetic hydrocarbon production from the Fischer–Tropsch process; biofuel production from energy crops or waste)

Hydrogen; ammonia; biofuels; synthetic fuels, including synthetic hydrocarbons

Life-cycle emissions assessments of liquid fuels (including production methods, e.g. low-carbon 'green' hydrogen vs. fossil fuel-derived 'blue'/'grey' hydrogen); discussion of carbon cost-effectiveness of technologies.

Networks and grid technologies – operating principles, merits and drawbacks:

Electricity networks

Smart grids (power systems with embedded communications)

Super grids (interconnection of power systems across large distances)

Digitalisation of energy services

Electricity demand flexibility

Hydrogen/gas networks

Heat networks.

Buildings:

Thermal efficiency of buildings

Local heat and power networks.

Energy storage technologies – operating principles, merits and drawbacks:

Electricity storage

Hydrogen/gas storage

Heat storage

Long-term energy storage.

Carbon capture, utilisation and storage (CCUS) technologies – operating principles, merits and drawbacks:

Carbon capture technologies

Utilisation of captured carbon

Storage options.

Achieving net zero:

Discussion of the need for GHG removal technologies

Discussion of nature- and technology-based solutions, including current level of development, scale and cost.

LO2 **Evaluate the suitability of different energy system infrastructure for meeting net zero targets in given geographical and socio-economic contexts**

Factors that influence geographical and socio-economic contexts:

Energy resources

Enabling low-carbon energy vectors

Existing infrastructure

Geopolitics

Geography

Climate

Land use

Energy economics.

LO3 **Analyse how net zero pathways are constructed for energy systems in a variety of geographical and socio-economic contexts**

Whole energy systems:

Interaction between different parts of the energy system

The need for whole-system approaches.

Development of net zero pathways:

Methodologies used for energy system pathway development

Scenario building

Energy systems modelling.

LO4 **Critically compare alternative net zero pathways for a given energy system.**

Net zero pathways for different sectors and different scales:

Net zero pathways (global/continental level; national-economy level; subnational-region level; sector level)

Net zero for businesses in the engineering and manufacturing sector.

Critical comparisons of alternative net zero pathways

Quantitative and qualitative comparison (e.g. life-cycle costs, cost of ownership)

Emissions scoping

Risks of reliance on technology

Risks of reliance on behavioural change.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore key changes to energy system infrastructure required for net zero		**D1** Evaluate the interactions between different elements of energy system infrastructure, including the impact of a change in one element on another.
P1 Explore the available technologies for energy system infrastructure required for net zero, including details of each technology's operating principles, main advantages and drawbacks.	**M1** Analyse future trajectories of the energy system and quantify the infrastructure required from a given net zero pathway.	
LO2 Evaluate the suitability of different energy system infrastructure for meeting net zero targets in given geographical and socio-economic contexts		**D2** Critically evaluate the suitability of energy system infrastructure for given different geographical and socio-economic contexts around the world with reference to life-cycle emissions assessments and the ability of these infrastructures to contribute to net zero.
P2 Evaluate the suitability of applying given energy system infrastructure to specified areas, given physical geographical factors (e.g. renewable resources from solar; requirements for long-distance electricity transmission).	**M2** Assess the suitability of energy system infrastructure to particular geographical and socio-economic contexts (e.g. renewable resources, local energy demand practices such as passenger transport and cooking).	

Pass	Merit	Distinction
LO3 Analyse how net zero pathways are constructed for energy systems in a variety of geographical and socio-economic contexts		
P3 Analyse how changes in behaviour can affect changes in energy demand and the related effects on infrastructure needs across different sectors of the energy system. **P4** Explain the need for whole systems thinking in developing net zero pathways.	**M3** Justify how engineers can account for uncertainty and risk in the development of net zero pathways.	**D3** Evaluate how sectors of the economy outside the energy system are impacted by net zero targets, including reference to how changes in these sectors affect emissions mitigation strategies in the energy sector.
LO4 Critically compare alternative net zero pathways for a given energy system.		
P5 Discuss how emissions accounting works at levels of national economy, subnational region, and organisation. **P6** Critically compare different net zero pathways at a given level for a particular sector.	**M4** Analyse the level of emissions scoping that is needed in various net zero pathways at different levels, including details of how emissions scoping impacts the actual emissions reductions deliverable from meeting a net zero target. **M5** Analyse methodologies used to develop energy system scenarios across different net zero pathways at various levels, including details of how these differences affect the results of these pathways.	**D4** Evaluate the risk of different net zero pathways at various levels, including assessments of risk associated with relying on the evolution of various technologies and social practice trends (e.g. carbon capture and storage vs. onshore wind; reduction in meat consumption vs. uptake of smart technologies).

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Berners-Lee, M. (2019) *There is no Planet B: A Handbook for the Make or Break Years*. Cambridge University Press.

Climate Assembly UK. (2020) *The path to net zero*. House of Commons.

Dixon, J., Brush, S., Fleet, G., Bell, K. and Kelly, N. (2021) *Energy Technologies for Net Zero.* The Institution of Engineering and Technology (IET).

MacKay, D.J.C. (2008) *Sustainable Energy – Without the Hot Air*. UIT Cambridge.

Sharma N. and Kumar P.D. (2023) *Towards Net-Zero Targets: Usage of Data Science for Long-Term Sustainability Pathways − Advances in Sustainability Science and Technology (Paperback).* Springer.

Zipse O., Hornegger J., Becker T., Beckmann M., Bengsch M., Feige I. and Schober M. (Editors) (2023) *Road to Net Zero: Strategic Pathways for Sustainability-Driven Business Transformation (Hardback).* Springer.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Baik, E., Chawla, K.P., Jenkins, J.D., et al. (2021) What is different about different net-zero carbon electricity systems? *Energy and Climate Change*, 2, 100046.

Bataille, C., Waisman, H., Briand, Y., et al. (2020) Net-zero deep decarbonization pathways in Latin America: Challenges and opportunities. *Energy Strategy Reviews*, 30, 100510.

DeAngelo, J., Azevedo, I., Bistline, J., et al. (2021) Energy systems in scenarios at net-zero CO_2 emissions. *Nature Communications*, 12(1), 6096.

Dixon, J., Bell, K. and Brush, S. (2022) Which way to net zero? A comparative analysis of seven UK 2050 decarbonisation pathways. *Renewable and Sustainable Energy Transition*, 2, 100016.

Links

This unit links to the following related units:

Unit 4005: Renewable Energy

Unit 4073: Sustainability and the Environment in the Manufacturing Industry

Unit 4089: Net Zero Energy Technologies I: Systems and Demand

Unit 5018: Sustainability

Unit 5045: Electrical Engineering and Sustainability.

Unit 5055: Aerospace Propulsion Principles and Technology

Unit Code: Y/650/9510

Level: 5

Credits: 15

Introduction

A propulsion system is one of the fundamental pillars of design and operation of aircraft and space vehicles. With an understanding that propulsion principles are different for aircraft and space flight, this unit introduces students to the thermodynamic and mechanical principles that underpin aircraft and rocket propulsion technologies. The unit is designed to examine the right balance of propulsion technologies, covering both atmospheric flight and space flight, with applications in commercial and military aircraft and launch vehicles/spacecraft for space exploration.

This unit explores different architectures of gas turbine and rocket engines, including their layout, working principle, function and operation, in addition to the typical selection process and testing of rocket engines for space-related missions.

Students will be able to learn how thermodynamic and mechanical principles are applied to aircraft and space propulsion, and about the construction, function and operation of gas turbine and rocket engines, with an emphasis on their selection and testing processes.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Determine how thermodynamic and mechanical principles are applied to aerospace propulsion

LO2 Examine the construction, function and operation of gas turbine engines and components

LO3 Examine the working principle, function and performance of rocket propulsion systems for aerospace applications

LO4 Describe the selection process and testing procedure for rocket engines for aerospace applications.

Essential Content

LO1 **Determine how thermodynamic and mechanical principles are applied to aerospace propulsion**

Thermodynamic principles applied to combustion engines:

The gas laws and the expansion and compression of perfect gases, constant volume, constant pressure, isothermal, adiabatic and polytropic processes

First law of thermodynamics applied to closed and open systems, non-flow (NFEE) and steady flow (SFEE) energy equations, concept of enthalpy in open systems, second law of thermodynamics applied to heat engines, measure of thermal efficiency

Thermal cycles and the concept of entropy, use of pressure–volume and temperature–entropy diagrams, the Joule/Brayton constant pressure cycle for gas turbine engines

The practical closed and open gas turbine cycle, losses compared with the ideal Joule/Brayton cycle; thermal and propulsive efficiencies and measure of specific fuel consumption in gas turbine engines.

Mechanical principles applied to fluid flow and propulsive thrust:

Newton's laws of motion applied to fluid flow; momentum and kinetic energy of fluid flow, use of continuity, Bernoulli equation and SFEE for incompressible gas flows; compressible sonic flows, Mach number and airflow velocities, static and stagnation conditions, jet nozzle flow, chocked nozzles

Newton's laws and aircraft thrust from gas stream; gross thrust, intake drag force, net thrust, net thrust with pressure thrust, thrust power

Appropriate calculations to support principles detailed above.

LO2 **Examine the construction, function and operation of gas turbine engines and components**

Types, construction and operation of gas turbine engines:

Turbojet engine: construction, arrangement and location of engine components and associated gearing and connections; operation, changes to the working fluid and the production of thrust as air/gas flows into the intake and through the compressor, combustor, turbine, propelling nozzle and exhaust components of the engine; operational limitations of the pure jet engine, noise pollution, reduced propulsive efficiency

Turbofan engine: construction, arrangement and operational differences between multi-shaft high bypass turbofan engines and the single-shaft turbojet; relative advantages of turbofan engines over turbojets, fuel and propulsive efficiency, cooling and noise reduction

Turboprop engine: construction, arrangement and component location, addition of low-pressure turbine, main gearbox and propeller; operational differences in the production of thrust via a propeller; relative advantages/disadvantages over turbofan engines

Turboshaft engine: construction, arrangement and component location, introduction of larger diameter driveshaft and more robust compressors and turbines; operation for the production of torque to drive helicopter rotors; relative advantages in the use of this type of engine.

Function and operation of gas turbine engine components:

Function and operation of compressors: axial flow compressors, stage rotors and stators, working fluid temperature and pressure rises and governing factors, inlet guide vanes, variable stator vanes; centrifugal compressors, inlet duct and vanes, the impeller, rotating guide vanes and radial diffuser vanes, airflow pressure rise and centrifugal action

Function and operation of fans: compression of bypass air, supercharged air feed into core, need for multi-stage fans and form of fan blade, disc, attachments and casing

Combustors: types, multiple-combustion chamber, tubo-annular and annular; requirements, high combustion efficiency, reliable ignition, restart facility, low-pressure losses and emissions, high durability; function and operation, control of combustible gases, fuel injectors, vaporisers, spray nozzles, ignitors and combustion chamber cooling

Function and operation of turbines: single and multi-stage, impulse and reaction turbines, energy transfer from the working fluid, turbine casing, discs, shafts and nozzle guide vanes, turbine cooling and constructional materials limitations

Function and operation of intakes and exhausts: intakes, bell-mouth, circular, variable geometry, drag minimisation at cruise speeds, integration with engine cowlings; exhausts, gas exhaust propelling nozzles, reverse thrusters, thrust-vectoring nozzles, afterburners

Appropriate calculations to support principles detailed above.

LO3 **Examine the working principle, function and performance of rocket propulsion systems for aerospace applications**

Rocket propulsion systems for aerospace:

Overview and classification of rocket propulsion: solid, liquid, hybrid and combined cycles, electrical and nuclear; application of rockets in launch vehicles and spacecraft

Performance characteristics of rocket engines: thrust equation, exhaust velocity, specific impulse and efficiencies

Solid propellant rocket engine fundamentals: performance relations, propellant burning rate, propellant grain and grain configurations; combustion processes in solid rockets, introduction to solid rocket motor design, safety characteristics and hazards of solid rockets

Liquid propellant rocket engine fundamentals: propellant types, liquid propellant properties, propellant feed systems, propellant tanks, engine cycles and combustion processes, safety and environmental concerns (e.g. use of green propellants)

Introduction to conventional bi-propellant systems and design of hybrid rocket

Introduction to electric propulsion: differences between classical rocket engines and electric propulsion, types of electric propulsion

Introduction to nozzle theory: thermodynamic characteristics, ideal rocket nozzle design, expansion processes, variable thrust and thrust vectoring

Appropriate calculations to support principles detailed above.

LO4 **Describe the selection process and testing procedure for rocket engines for aerospace applications**

Rocket engines for aerospace:

Selection processes for rocket propulsion systems for mission applications: defining mission requirements, vehicle configuration and flight regime, available choices and evaluation of candidate propulsion systems, selection criteria; advantages and disadvantages of solid and liquid propellant rocket engines in the context of selection process for launch and space missions; integration and interfacing of rocket engines with the launch/space vehicles; selection and design in the context of human space missions and interplanetary missions

Review of rocket propulsion techniques used in various space missions by international agencies e.g. National Aeronautics and Space Administration (NASA), European Space Agency (ESA), Indian Space Research Organisation (ISRO)

Testing of rocket propulsion systems: types of test, manufacturing inspection of engine parts, functional and operational tests of engine components, static rocket propulsion system tests with complete propulsion system, static vehicle tests with engine installed in restrained, non-flying vehicle, full flight tests

Test facilities and safety protocols

Instrumentation, measurements and data management.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine how thermodynamic and mechanical principles are applied to aerospace propulsion		
P1 Synthesise the use of thermodynamic principles applied to aircraft gas turbine engine operating cycles as part of reviewing a given work-related scenario. **P2** Determine how the mechanical principles apply to the production of propulsive thrust by gas turbine engine-driven aircraft.	**M1** Explain, with the use of calculations, the thermodynamic and mechanical principles applied to the operating cycles and production of propulsive thrust by gas turbine engine-driven aircraft.	**D1** Analyse the thermodynamic and mechanical principles applied to the operating cycles and production of propulsive thrust by gas turbine engine-driven aircraft.
LO2 Examine the construction, function and operation of gas turbine engines and components		
P3 Illustrate the construction and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines. **P4** Examine the function and operation of gas turbine engine, intake, compressor, combustor, turbine and exhaust components.	**M2** Explore the construction, function and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines and their components, identifying, with calculations, the relative performance of each engine type.	**D2** Analyse the constructional features, function and operation of turbojet, turbofan, turboshaft and turboprop gas turbine engines and their components, assessing the relative performance of each engine and component arrangement.

Pass	Merit	Distinction
LO3 Examine the working principle, function and performance of rocket propulsion systems for aerospace applications		
P5 Explain the working principle of a simple rocket propulsion system. **P6** Examine the function and operation of solid, liquid and hybrid rocket propulsion engines.	**M3** Analyse the performance characteristics of ideal rocket engines using one-dimensional thermodynamic calculations.	**D3** Distinguish various rocket propulsion systems based on their working principles and performance characteristics.
LO4 Describe the selection process and testing procedure for rocket engines for aerospace applications		
P7 Describe the overall approach towards selection of rocket engines for a given mission. **P8** Explain various levels of testing, starting from part inspection to functional, operational, system and flight tests.	**M4** Describe the testing procedure with reference to test facilities, measurements and safety protocols.	**D4** Analyse the key factors and criteria used in the evaluation and selection of specific propulsion systems.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Farokhi, S. (2021) *Aircraft Propulsion: Cleaner, Leaner, and Greener*. 3rd Ed. Hoboken, NJ: John Wiley & Sons.

Farokhi, S. (2020) *Future Propulsion Systems and Energy Sources in Sustainable Aviation – Aerospace Series.* Chichester: John Wiley & Sons.

Heister, S.D., Anderson, W.E., Pourpoint, T.L. and Cassady, R.J. (2019) *Rocket Propulsion – Cambridge Aerospace Series.* Cambridge: Cambridge University Press.

Kumar, K.S., Narayanaswamy, I. and Ramesh, V. (2021) *Design and Development of Aerospace Vehicles and Propulsion Systems: Proceedings of SAROD 2018: Lecture Notes in Mechanical Engineering.* Singapore: Springer Nature.

Rolls-Royce (2015) *The Jet Engine.* 5th Ed. Chichester: John Wiley & Sons.

Saravanamuttoo, H.I.H., Rogers G.F.C., Cohen, H., Nix, A. and Straznicky, P.V. (2017) *Gas Turbine Theory*. 7th Ed. Harlow: Pearson Education.

Sutton, G.P. and Biblarz, O. (2017) *Rocket Propulsion Elements*, 9th Ed. Hoboken, NJ: John Wiley & Sons.

Turner, M.J.L. (2009) *Rocket and Spacecraft Propulsion: Principle, Practice and New Developments*. 3rd Ed. Chichester: Praxis Publishing.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Aerospace

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

Journal of Aerospace Engineering

Journal of Aircraft

Journal of Propulsion and Power

Journal of Spacecraft and Rockets

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Transfer

Unit 5005: Further Thermodynamics

Unit 5027: Aircraft Propulsion Principles and Technology

Unit 5030: Aircraft Gas Turbine Engine Design and Performance.

Unit 5056: Conceptual Aircraft Design

Unit Code: A/650/9511

Level: 5

Credits: 15

Introduction

In a world where aviation continues to shape global connectivity and transportation, the art of conceptual aircraft design stands as a pivotal starting point for the aircraft design and development process. As the aerospace industry evolves, the importance of creating aircraft that are not only technologically advanced but also efficient, safe and environmentally conscious has become increasingly evident.

To enable next-generation engineers to design and build efficient aircraft, this unit introduces students to the fundamental principles and methodologies involved in the conceptual design process of an aircraft. Students will explore weight-estimation techniques, enabling them to understand the implications of design decisions on aircraft performance. Delving into wing, tail and fuselage layouts, students will grasp the delicate balance between aerodynamics, structural integrity and aesthetics. Power plant selection will enable students to align propulsion systems with design objectives and environmental standards. The unit also covers landing gear design and culminates in cost estimation, preparing students to balance innovation with practicality.

In this unit, students will learn about aircraft design procedures. They will be enabled to conduct a conceptual design of an aircraft for given mission requirements in terms of weight, layout and choice of power plants, with an awareness of the cost and regulatory aspects of aircraft design and development.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Assess the weight estimations of the aircraft and its components given its type, mission and aerodynamic, structural and propulsion system characteristics

LO2 Illustrate the aircraft configuration layout, considering the wing, tail, fuselage and associated characteristics

LO3 Establish various power plant and landing gear configurations for aircraft design

LO4 Explain various elements of aircraft life cycle cost and the cost-estimation procedure for aircraft design and development.

Essential Content

LO1 **Assess the weight estimations of the aircraft and its components given its type, mission and aerodynamic, structural and propulsion system characteristics**

Overview of aircraft design:

Overview of the aircraft design process

Requirements and specifications for civil and military aircraft

Different stages of airplane design

Various types of aircraft configurations, factors affecting them and their merits

Conceptual design sketch from requirements

Introduction to unique aircraft design concepts, including electric airplanes.

Weight estimation:

Aircraft sizing, empty weight estimation, fuel-fraction estimation, mission-segment weight fractions

Take-off weight calculations, iterative sizing procedure.

LO2 **Illustrate the aircraft configuration layout, considering the wing, tail, fuselage and associated characteristics**

Aerofoil selection:

Aerofoil geometry, lift and drag characteristics, different aerofoil families.

Main wing geometry, tailplane and fuselage design:

Wing aspect ratio, wing sweep, taper ratio, wing twist

Wing incidence and dihedral, wing location, wing tip design

Different types of tailplane arrangements/positioning

Tail geometry: area estimation, tail volume coefficient, aspect ratio and taper

Sizing of fuselage and control surfaces.

Thrust-to-weight ratio and wing-loading estimation in aircraft design:

Calculations based on stall speed, take-off and landing distance

Thrust-to-weight ratio and wing-loading estimations for various flight phases.

Configuration layout:

Fuselage and wing/tail lofting and layout

Wing/tail cross-section layout

Wetted area and aircraft internal volume

Other aerodynamic, structural and manufacturability considerations.

LO3 **Establish various power plant and landing gear configurations for aircraft design**

Selection of propulsion systems:

Types of power plant for aircraft: piston-propeller, turboprop, turbofan and turbojet engines, with and without afterburners.

Engine dimensions and locations, fuel system design and integration

Jet engine integration and propeller engine integration.

Landing gear configuration:

Type and arrangements, retraction mechanisms and landing loads and shock absorption.

LO4 **Explain various elements of aircraft life cycle cost and the cost-estimation procedure for aircraft design and development**

Life cycle cost and estimation:

Elements of life cycle cost, cost-estimation method (e.g. RAND DAPCA IV model), operation and maintenance costs, the economics of aircraft and airline operations, case studies on the design of civilian and military aircraft.

Regulatory requirements:

Regulatory (e.g. health and safety, environmental, risk assessments) and certification requirements (e.g. records, audits, training) and their influence on aircraft design (e.g. airworthiness of the aircraft or component) and cost for commercial and military airplanes

Team approach to meeting regulatory and key stakeholder requirements and needs.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Assess the weight estimations of the aircraft and its components given its type, mission and aerodynamic, structural and propulsion system characteristics		
P1 Assess estimates of the mission-segment weight fractions for commercial and military aircraft mission requirements. **P2** Describe the three different stages of the aircraft design process.	**M1** Determine take-off weight using the iterative procedure for a given aircraft type and mission requirements.	**D1** Conduct parametric trade studies to critically evaluate take-off weight, considering different trade cases.
LO2 Illustrate the aircraft configuration layout, considering the wing, tail, fuselage and associated characteristics		
P3 Illustrate the lift, drag and pitching moment characteristics of a typical aerofoil using appropriate plots. **P4** Describe the influence of various wing geometric features on the resulting aerodynamic characteristics. **P5** Determine the thrust-to-weight ratio of an aircraft using thrust matching during cruise, followed by the thrust-to-weight ratio calculations in climb and take-off phases.	**M2** Evaluate wing loading based on specified requirements in terms of stall speed, take-off distance, range and loiter endurance, glide and climb and maximum ceiling.	**D2** Synthesise the geometric design sketch of the airplane using sizing calculations for fuselage, tail and control surfaces and other information.

Pass	Merit	Distinction
LO3 Establish various power plant and landing gear configurations for aircraft design		
P6 Establish the requirements for power plants for various aircraft types depending on the mission definitions. **P7** Describe various types of landing gear and their arrangements for different design requirements.	**M3** Estimate engine weight for a jet engine-powered commercial airplane using statistical jet engine models.	**D3** Analyse the key differences in design among piston-propeller, turboprop, turbofan and turbojet engines, with and without afterburners.
LO4 Explain various elements of aircraft life cycle cost and the cost-estimation procedure for aircraft design and development		
P8 Explain key elements of aircraft life cycle cost from design to build and operation. **P9** Describe two different cost-estimation methods followed in the aircraft design process.	**M4** Conduct cost-estimation exercise using the RAND DAPCA IV model for a given aircraft design.	**D4** Critically discuss aircraft and airline economics in terms of operating costs, revenue and break-even analysis.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Anderson, J.D. (2010) *Aircraft Performance and Design*. London: McGraw-Hill Education.

DeLaurier, J. (2022) *Aircraft Design Concepts: An Introductory Course*. Boca Raton, Florida: CRC Press.

Gudmundsson, S. (2020) *General Aviation Aircraft Design*. 2nd Ed. Oxford: Butterworth-Heinemann.

Jackson, S. and Moraes dos Santos, R. (2020) *Systems Approach to the Design of Commercial Aircraft*. Boca Raton, Florida: CRC Press.

Kundu, A.K., Price, M.A. and Riordan, D. (2019) *Conceptual Aircraft Design: An Industrial Approach*. Hoboken, NJ: John Wiley & Sons.

Raymer, D.P. (2018) *Aircraft Design: A Conceptual Approach (AIIA Education Series)*. 6th Ed. Reston, Virginia: American Institute of Aeronautics and Astronautics.

Seabridge, A. and Radaei, M. (2022) *Aircraft Systems Classifications: A Handbook of Characteristics and Design Guidelines*. Hoboken, NJ: John Wiley & Sons.

Sterkenburg, R. and Kroes, M. (2019) *Aircraft Maintenance & Repair*. 8th Ed. New York: McGraw-Hill Education.

Torenbeek, E. (1982) *Synthesis of Subsonic Airplane Design*. Cham, Switzerland: Springer Nature. *Note: This book was reprinted in 2010.*

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject-specific knowledge and skills as part of unit level delivery.

Aerospace

AEROSPACE Magazine

Aerospace Science and Technology

Aerospace Systems

AIAA Journal

Aircraft Engineering and Aerospace Technology

Journal of Air Transport Management

The Aeronautical Journal

Links

This unit links to the following related units:

Unit 4041: Aircraft Aerodynamics (minimum pre-requisite)

Unit 5027: Aircraft Propulsion Principles and Technology

Unit 5028: Aircraft Structural Integrity.

Unit 5057: Medical Instrumentation

Unit Code: F/650/9513

Level: 5

Credits: 15

Introduction

Medical instrumentation refers to the specialised devices, equipment and instruments used in healthcare settings for various purposes, including diagnosing, monitoring and treating medical conditions. These instruments are specifically designed to interact with the human body, collect physiological data and provide accurate measurements or deliver therapeutic interventions.

The aim of this unit is to provide students with a comprehensive understanding of medical instrumentation principles, design considerations and applications. Students will develop the knowledge and skills necessary to design, analyse and evaluate medical instruments used in healthcare settings. Students will learn about the signals that are often produced by medical instruments (biomedical signals) and equip students with the competence required to critically analyse and interpret biomedical signals and apply relevant signal processing techniques. The unit will foster an understanding of regulatory requirements and safety considerations in the design and use of medical instruments and promote ethical decision-making in the context of medical instrumentation design.

On successful completion of this unit students will have developed the knowledge, skills and behaviours necessary to design, analyse and evaluate medical instruments used in healthcare settings. They will be equipped to engage in the maintenance, design and development of biomedical devices and systems, supporting advancements in healthcare technology.

Learning Outcomes

By the end of this unit, students will be able to:

LO1 Demonstrate knowledge of medical instrumentation design, testing and performance evaluation in the context of applications and usage in clinical practice

LO2 Explain biomedical signal processing techniques and their significance in medical applications

LO3 Analyse biomedical signals acquired through medical instruments

LO4 Apply the regulatory requirements and quality and safety considerations related to medical instruments.

Essential Content

LO1 **Demonstrate knowledge of medical instrumentation design, testing and performance evaluation in the context of applications and usage in clinical practice**

Overview of medical instrumentation design:

Purpose, principles and significance of medical instrumentation

Requirements and design considerations (e.g. compliance) in medical instrumentation

Testing, maintenance and repairs in medical instrumentation

Human factors and user-centred design in medical instruments

Disposal.

Sensors and electrodes:

Measurement of physical quantities e.g. temperature, pressure, optical, electrical, flow, position

Concepts of range, calibration, precision and reliability

Calibration techniques for accurate measurements.

Types and applications of medical instrumentation:

Therapeutic devices: pacemakers, defibrillators, ventilators

Monitoring devices: electrocardiography (ECG) monitors, blood pressure monitors

Imaging systems: radiography systems, ultrasound equipment.

LO2 **Explain biomedical signal processing techniques and their significance in medical applications**

Signal amplification:

Use of different types of sensor/detector and latest advancements

Operational amplifiers in medical instrumentation

Isolation amplifiers

Active filters for bio signals.

Signal processing:

Analogue-to-digital conversion of bio signals with example applications

Digital-to-analogue conversion of bio signals with example applications

Filtering techniques

Software signal processing methods in medical instrumentation.

LO3 **Analyse biomedical signals acquired through medical instruments**

Nature and characteristics of biomedical signals:

Biopotentials: electrocardiography (ECG), electromyography (EMG) and electroencephalography (EEG) and their acquisition and interpretation

Digital thermometer design and development

Non-invasive optical measurements of blood oxygenation

Examples of use of data/information derived from biomedical signals.

Bio signal acquisition and analysis:

Signal analysis techniques and associated advancements/challenges in the biomedical sector

Physiological measurements using a simulator

Design and fabrication of instrumentation

Analogue-to-digital conversion.

LO4 **Apply the regulatory requirements and quality and safety considerations related to medical instruments**

Safety and regulation:

Regulatory frameworks and safety measures

Market approval of medical instruments

Electrical safety testing of medical instruments

Compliance with standards and regulations

Patient safety and device effectiveness.

Ethical and societal considerations:

Ethical implications in medical instrumentation design

Patient privacy, patient dignity, informed consent or equivalent (e.g. valid consent) and data security

Equitable access and societal impact of medical instruments.

Device quality testing and evaluation:

Quality control

Limitations and error sources

Environmental, biological and user-dependent factors

Assessment of technological limitations.

Cost-effectiveness:

Benefits and value

Potential impact on patient outcomes and healthcare costs.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Demonstrate knowledge of medical instrumentation design, testing and performance evaluation in the context of applications and usage in clinical practice</td><td rowspan="4">LO1 and LO2
D1 Demonstrate proficiency in assessing and testing device performance against specifications and device compliance against the evaluation criteria, and in planning for corrective actions in cases of device non-compliance within the industry context.
D2 Critically justify the use of signal processing techniques to effectively address specific challenges or requirements in healthcare.</td></tr>
<tr><td>P1 Explain the principles and requirements of medical instrumentation design.
P2 Discuss the main applications of medical instruments in clinical practice.
P3 For a given context, demonstrate how to choose the key parameters and performance metrics that are crucial for the successful development or maintenance of a clinically effective medical device.</td><td>M1 Analyse the design requirements of a chosen category of medical instruments.</td></tr>
<tr><td colspan="2">LO2 Explain biomedical signal processing techniques and their significance in medical applications</td></tr>
<tr><td>P4 Explain the key types of sensor used in medical instrumentation.
P5 Examine signal amplifiers for a practical system in a chosen clinical application.</td><td>M2 Assess bio signal processing requirement(s) for a particular medical instrument.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Analyse biomedical signals acquired through medical instruments		**LO3 and LO4**
P6 Explain the main signal analysis techniques used in biomedical applications and their significance in addressing the challenges associated with the quality of biomedical signals. **P7** Analyse the usefulness of information extracted from biomedical signals.	**M3** Display practical skills in acquiring and analysing a raw biomedical signal.	**D3** Demonstrate expertise in the acquisition, analysis and interpretation of biomedical signals. **D4** Critically evaluate the main regulatory and electrical safety requirements of medical instruments, based on their intended use.
LO4 Apply the regulatory requirements and quality and safety considerations related to medical instruments		
P8 Apply understanding of the rationale and importance of regulatory compliance in the medical industry, including the key steps for obtaining market approval for medical instruments. **P9** Explain the main principles of electrical safety testing of medical devices.	**M4** Analyse the safety considerations associated with medical instruments.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Banerjee, A., Chakraborty, C., Kumar, A. and Biswas, D. (2020) 'Emerging trends in IoT and big data analytics for biomedical and health care technologies'. In *Handbook of Data Science Approaches for Biomedical Engineering*, pp. 121–152. London: Academic Press.

Boccato, C., Cerutti, S. and Vienken, J. (2022) *Medical Devices: Improving Health Care Through a Multidisciplinary Approach.* Cham, Switzerland: Springer Nature.

Bronzino, J.D. and Peterson, D.R. (2017) 'Medical Devices and Human Engineering'. In *The Biomedical Engineering Handbook*, Volume 2. 4th Ed. Boca Raton, Florida: CRC Press.

Cohen, I.G., Minssen, T., Price II, W.N., Robertson, C. and Shachar, C. (2022) *The Future of Medical Device Regulation: Innovation and Protection.* Cambridge: Cambridge University Press.

Elahi, B. (2021) *Safety Risk Management for Medical Devices.* 2nd Ed. London: Academic Press.

Paul, S., Saikia, A., Majhi, V. and Pandey, V.K. (2022) *Introduction to Biomedical Instrumentation and Its Applications.* London: Academic Press.

Webster, J.G. and Nimunkar, A.J. (2020) *Medical Instrumentation: Application and Design.* 5th Ed. Hoboken, NJ: John Wiley & Sons.

Websites

www.medgadget.com	Medgadget (General reference)
www.ni.com/en	National Instruments (General reference)
physionet.org/	PhysioNet (General reference)
physionet.org/	ScienceDirect (General reference)

Journals

Academic Radiology

Annals of 3D Printed Medicine

Biocybernetics and Biomedical Engineering

Biomedical Engineering Advances

Biomedical Engineering Letters

Biomedical Instrumentation and Technology

Biomedical Signal Processing and Control

Current Opinion in Biomedical Engineering

Medical Instrumentation

Medicine in Novel Technologies and Devices

Indicative equipment and other resources

Passive components and essentials e.g. resistors, capacitors, operational amplifers (op-amps), breadboards

Signal generator

Oscilloscope

Digital multimeter

AC/DC power supply

Data acquisition system, card and software (e.g. National Instruments)

Patient/biosignal simulator (e.g. Fluke)

Note: This is not an exhaustive list and should only be used as a general guide in planning for suitable resources. Examples indicate the varied scope of facilities other institutions offer to aid delivery of the subject.

Links

This unit links to the following related units:

Unit 4032: Introduction to Biomedical Engineering

Unit 5058: Automotive Structures and Materials

Unit Code: **Y/651/3074**

Level: **5**

Credits: **15**

Introduction

Vehicles are a collection of complex structures working in harmony, where rigorous and insightful design is key to producing robust solutions optimised for crashworthiness, aerodynamics and sustainability, impacting everything from production processes to end-of-life vehicle recycling. Every aspect of a vehicle – from the tyres to the roof – requires a thorough understanding of the science behind structures and materials to analyse and design efficient vehicle structures that meet the ever-evolving needs of the automotive sector. This continuous evolution plays a crucial role in meeting increasingly stringent environmental regulations and consumer demands for safer, more efficient vehicles. Consequently, the field of automotive engineering has seen growth in job roles. Typical duties and responsibilities of automotive structural engineers and automotive materials engineers include: selecting and developing materials for the durability and structural integrity of vehicle designs; developing advanced composites and materials to enhance crashworthiness and vehicle longevity; and driving the evolution of the automotive industry towards producing safer, more efficient, economical and greener vehicles, to align with global demands for environmental responsibility and advanced mobility solutions.

The aim of this unit is to equip students with the necessary knowledge and skills to design vehicle parts, structures, and systems, and to choose the best materials for the task based on project-specific design criteria. Whether the intention is to work as a supplier, at an Original Equipment Manufacturer (OEM) company, as a technician, or as a manager, this unit will provide the essential knowledge required to understand this complex discipline and ensure career progression.

Throughout this unit, students will make clear links between engineering principles, cause and effect, and the importance of design for purpose. Students will study safety and conformity for drivers and passengers, regulations, standards and governing bodies within the automotive sector.

By the end of this unit, students will have gained a systematic understanding of the design and analysis of automotive structures, and selection and use of a range of materials for the structures, along with the skills necessary to apply the knowledge in a real-world context.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Discuss automotive structures and materials, including structural form and function, material properties and limitations, and regulation and control

LO2 Assess automotive structures and materials for safety and crashworthiness

LO3 Analyse automotive system structural and material requirements based on their intended function and purpose

LO4 Design an automotive structure by selecting appropriate materials with testing against industry benchmarks.

Essential Content

LO1 **Discuss automotive structures and materials, including structural form and function, material properties and limitations, and regulation and control**

Automotive structures:

The history of automotive structures: development of main body structures and subsystems; drivetrain, powertrain, chassis and suspension, safety systems

Forms of structures in automotive applications

Vehicle dynamics: axis systems, equations of motion.

Automotive materials:

The history of automotive materials: wood, rubber, metals, aluminium and alloys

Composites: fibreglass, natural options, carbon fibre and resins, fabrics, cores, layering and structures

Bonding and fixing: glues, epoxies, rivets, nuts and bolts, welding (spot and seam), solid fixings, bushes, bearings, rose joints.

Regulations and controls:

Regulatory bodies: NCAP, VIA, JWL, TUV etc.

Certification and control: type approval, IVA, MoT, country specific regulations; current regulation and vehicle safety standards; safety first culture and relevant documentation

Noise vibration and harshness (NVH)

Environmental impact and considerations: end-of-life, recycling, life of and replacement of components.

LO2 **Assess automotive structures and materials for safety and crashworthiness**.

Structural assessment methods:

Structural engineering mathematics: stress, strain, yield, shear, twist, moments, fatigue

Simulations: finite element analysis, safety factors, displacements, stress and strain

Physical testing: pre-approval machine testing, repeat testing, concept trials.

Material assessment methods:

Sample testing, crack testing, ultrasonic testing

Simulation: static and dynamic analysis

Practical application and use of equipment

Specifications and standards: industry requirements, supplier specifications.

Safety and crashworthiness:

Structural techniques: crumple zones, side impact protection, roll over protection

Specialist applications: competition, commercial, industrial, law enforcement etc.

LO3 **Analyse automotive system structural and material requirements based on their intended function and purpose.**

Vehicle system and subsystem applications:

Vehicle application: system requirement variation across vehicle types; standard road vehicle, sports and performance, utility vehicles, commercial and heavy goods vehicles (HGVs)

Subsystems: towing, winching, change of purpose/classification (commercial to camper van etc.) and general after-market modifications

Material requirement by power source (e.g. IC engine, Li-on, hydrogen powered).

Key factors in structural selection:

Reliability versus cost

Strength versus weight

Quality versus benchmarks

Environmental considerations including consumer/market perspective.

Key factors in material selections:

Reliability versus cost

Strength versus weight

Quality versus benchmarks

Environmental considerations including consumer/market perspective.

LO4 **Design an automotive structure by selecting appropriate materials with testing against industry benchmarks**

Real-world design and test:

Use of technical drawings

Practical processes and procedures for structural manufacturing

Industry benchmark tests.

Virtual environment design and test:

CAD (computer-aided design) techniques for effective design

Structural and material simulation analysis software packages.

Industry 4.0 for automotive structures:

Concepts, design and testing implications: impact at the department/ organisation level including the integration of automation, digital systems and manufacturing engineering systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss automotive structures and materials, including structural form and function, material properties and limitations, and regulation and control		**LO1 and LO2**
P1 Determine common fixtures and materials used in the automotive industry. **P2** Discuss the main regulations relating to automotive structures and materials.	**M1** Analyse limitations of materials commonly used in automotive manufacture.	**D1** Evaluate the current methods of structural design and material selection with proposals for progression and evolution.
LO2 Assess automotive structures and materials for safety and crashworthiness		
P3 Investigate the evolution of automotive structures in terms of safety and crashworthiness. **P4** Assess the quality of current automotive materials in terms of safety and crashworthiness.	**M2** Analyse the current regulation and control implementations in automotive manufacturing.	

Pass	Merit	Distinction
LO3 Analyse automotive system structural and material requirements based on their intended function and purpose		**LO3 and LO4**
P5 Analyse a specific automotive application in terms of structural and material suitability. **P6** Analyse a historic automotive structure for alternative methods of development for the market of today.	**M3** Analyse the thermal implications and risks of using composite materials in high-performance applications.	**D2** Critically analyse the results of testing an automotive structure with design suitability examined in terms of structure and material choices.
LO4 Design an automotive structure by selecting appropriate materials with testing against industry benchmarks		
P7 Design an automotive structure or a subsystem in line with the industry standards. **P8** Analyse alloys and composites that could be used for a designed structure.	**M4** Test a structural design with a selection of materials chosen.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Bosch, Robert, GmbH. (2022) *Bosch Automotive Handbook*. 11th Ed. New Jersey: Wiley.

Dieter, G.E. and Schmidt, L.C. (2013) *Engineering Design*. McGraw Hill.

Faruk, O., Tjong, J. and Sain, M. (2017) *Lightweight and Sustainable Materials for Automotive Applications.* Florida: CRC/Taylor & Francis.

Gillespie, T.D. (2021) *Fundamentals of Automobile Body Structure Design.* Revised 1st Ed. London: SAE International Books.

Greene, J.P. (2021) *Automotive Plastics and Composites: Materials and Processing.* Norwich: William Andrew Publishing.

Kobelev, V. (2019) *Design and Analysis of Composite Structures for Automotive Applications: Chassis and Drivetrain.* New Jersey: Wiley.

Malen, D.E. (2020) *Fundamentals of Automobile Body Structure Design.* 2nd Ed. London: SAE International Books.

Sapuan, S.M., Ilyas, R.A. and Asyraf, M.R.M. (2022) *Safety and Health in Composite Industry*. New York: Springer Publishing.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Molker, H., Gutkin, R. and Asp, L. (2019) 'Industrial framework for identification and verification of hot spots in automotive composite structures', *SAE International*, 12(2) pp. 107–120.

Tyan, T., Aekbote, K., Chen, G. and Todd, M. (2020) 'Crashworthiness performance of multi-cornered structures under quasi-static compression and dynamic axial loading conditions', *SAE International*, 14(2), pp. 153–193.

Zhou, X., Jiang, J., Hu, Z. and Hua, L. (2022) 'Lightweight materials in electric vehicles', *International Journal of Automotive Manufacturing and Materials*, 1(1), pp. 3

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 4003: Engineering Science I

Unit 4009: Materials, Properties and Testing

Unit 4028: Materials Engineering with Polymers

Unit 4035: Welding Technology

Unit 4063: Engineering Mechanics and Materials

Unit 4091: Automotive Fundamentals

Unit 4092: Vehicle Dynamics and Performance

Unit 4093: Race Car Design and Manufacturing

Unit 4097: Electric Vehicle Battery Manufacture

Unit 4099: Industrial Digitalisation Technologies for Engineers

Unit 4112: Vehicle Repair and Diagnostics

Unit 5018: Sustainability

Unit 5060: Motorsport Workshop Preparation and Inspection

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 5068: Vehicle Parts Management

Unit 5059: Automotive Aerodynamics

Unit Code: A/651/3075

Level: 5

Credits: 15

Introduction

Aerodynamics is crucial in automotive design, as it influences how vehicles interact with air to boost efficiency, performance and stability. As a vital field within automotive engineering, aerodynamicists work to refine vehicle shapes to minimise drag and enhance fuel efficiency, aligning with strict global emissions standards and market demands. Techniques such as computational fluid dynamics (CFD), wind-tunnel testing and on-road trials are essential for visualising and optimising airflow. The shift from basic design tweaks to advanced aerodynamic innovations marks a dynamic sector teeming with professional opportunities. With leading automotive manufacturers and Formula One teams consistently pursuing innovations, the scope for careers in aerodynamics is broad, ranging from entry-level roles to department leadership positions.

The aim of this unit is to equip students with specialised knowledge and skills to theorise, design and validate effective aerodynamic solutions, preparing them for immediate employment and career advancement not only within the automotive sector but also across the broader engineering field.

Topics covered in this unit include: the fundamental theories of aerodynamics; the interaction of solids, fluids, and gases; and the critical role of shape and size in determining vehicular travel efficiency. Students will explore the parametric and mathematical design of systems or subsystems, alongside design constraints such as regulatory compliance, safety and consumer preferences.

On completion of this unit, students will possess a comprehensive understanding of automotive aerodynamics and the practical skills necessary for a career as an aerodynamicist. Through work-related scenarios, they will critically assess, design, test and analyse aerodynamic objects, readying them for challenges in the automotive industry.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Discuss principles of automotive aerodynamic design

LO2 Examine vehicle designs and aerodynamic subsystems and their effectiveness

LO3 Analyse aerodynamic designs to make informed recommendations for improvement of functional purpose

LO4 Design an aerodynamic system with testing performed against the industry benchmarks.

Essential Content

LO1 **Discuss principles of automotive aerodynamic design**

Fundamental of vehicle design:

Automotive vehicle types: passenger car, sports car, utility vehicles, commercial vehicles, specialist vehicles such as motorbikes

Vehicle axis and planes vertical: lateral and longitudinal axis, plan, profile and frontal view planes

Vehicle dynamic terminologies: acceleration, deceleration, pitch, yaw, roll, bump, rebound, traction, oversteer, understeer

Vehicle design regulation: safety, conformity, environmental and legal requirements; region-specific regulations and application (e.g. BS/EU/ISO).

Principles of aerodynamics:

Aerodynamic terminologies: drag, lift, negative lift, downforce, yaw, moment forces, centre of pressure, aerodynamic balance

Aerodynamic mathematics: formulae for drag and drag coefficient, lift and lift coefficient, Reynolds number, drag versus engine power, lift-to-drag ratios and aerodynamic efficiency

Design for efficiency

Design for safety

Design for performance.

Automotive and aerodynamic design theory:

Automotive aerodynamics design cycles: sketching, scale and full size model making, case studies, focus groups, parametric requirements

Real-world and virtual-world design: 3D scanning, reverse engineering and rapid prototyping

Virtual design: 2D into glass box designs, wire view, surface and component modelling; use of advanced computer models, CFD simulations; principles of quality control and quality assurance.

LO2 **Examine vehicle designs and aerodynamic sub systems and their effectiveness**

Vehicle design and aerodynamic impact:

Origins of the automobile: design and evolution of aerodynamics (good or bad) through the generations

Vehicle design limitations: evolution of regulations and safety systems over time, vehicle type approval, governance and environmental agendas/ requirements.

Vehicle systems and subsystems:

Vehicle body design: consumer focus, manufacturer design language, unavoidable form aspects of functional requirements and approach

Vehicle subsystems: bolt-on and upgrade components for acoustics, efficiency, performance and safety

Active aerodynamics: efficiency systems, safety systems, performance systems for aerodynamics.

Validation techniques:

Real-world testing: run downs, sensors and actuators, viability and safety considerations/limitations

Wind-tunnel testing: processes and procedures, requirements, pros and cons, financial implications

Virtual simulation: computation fluid dynamics (CFD), static and dynamic simulation, governing equations

Computation requirements simulation licencing, computer specifications and simulation complexities

Correlation and validation techniques: aero maps and data sets, mathematical validation, test data comparison, accuracy and compensation considerations, finite element analysis (FEA) strength validation.

LO3 **Analyse aerodynamic designs to make informed recommendations for improvement of functional purpose**

Analyse designs for purpose:

Benchmarking: industry standards and trends

Analysis of existing systems for economic efficiency such as ducting, diverted plates, wake control, spoiler and splitters, active grille and wake controlling systems, DRS (drag reduction systems)

Analysis of existing systems and subsystems for dynamic performance.

Methods of analysis validation:

Visual analysis: flow versus fluids, smoke wands, streamlines, vector and scalar scenes

Mathematical analysis: data comparison in charts, graphs and tables.

The importance of analysis:

Aerodynamic history, study problems that require aerodynamic redesign, acoustic issues, safety issues, flow irregularities and other negative aerodynamic occurrences requiring thought and redesign.

LO4 **Design an aerodynamic system with testing performed against the industry benchmarks.**

Automotive vehicle design:

Designing vehicle bodies to compare against industry standard data for drag coefficients

Run CFD simulations to gain necessary data to compare against benchmark figures

Tabulate relevant data to compare against benchmark figures

Create visualisations that provide visual context to a chosen design narrative.

Vehicle aerodynamic subsystem design:

Creating improved aerodynamic designs of vehicle sub systems based on a chosen narrative, economy, sporting performance, safety improvements

Run CFD simulations to gain necessary data to compare against benchmark figures.

Tabulate relevant data to compare against benchmark figures

Create visualisations that provide visual context to a chosen design narrative.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss principles of automotive aerodynamic design		**LO1 and LO2**
P1 Discuss the key factors affecting automotive aerodynamics. **P2** Analyse aerodynamic data to determine vehicle performance characteristics.	**M1** Evaluate, using theoretical calculations, the aerodynamic performance of vehicles and how the results can be used to benchmark performance.	**D1** Critically evaluate, using supporting calculations, automotive aerodynamic systems and subsystems for efficiency, performance and safety.
LO2 Examine vehicle designs and aerodynamic subsystems and their effectiveness		
P3 Assess the purpose and effectiveness of active aerodynamic systems. **P4** Examine the correlation of data obtained from real-world testing and simulation testing.	**M2** Analyse the impact of adding passive and active aerodynamic components to a road vehicle.	

Pass	Merit	Distinction
LO3 Analyse aerodynamic designs to make informed recommendations for improvement of functional purpose		**LO3 and LO4** **D2** Critically analyse the redesign of an aerodynamic vehicle body against a base model to validate design success.
P5 Analyse aerodynamic data sets for a given scenario or vehicle. **P6** Propose improvements to existing vehicle aerodynamic designs.	**M3** Demonstrate a methodical approach to aerodynamic design optimisation.	
LO4 Design an aerodynamic system with testing performed against the industry benchmarks.		
P7 Design an aerodynamic vehicle body. **P8** Test an aerodynamic vehicle body.	**M4** Propose effective design level changes to the functioning of an aerodynamic vehicle body.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Barnard, R.H. (2022) *Road Vehicle Aerodynamic Design: An Introduction.* 2nd Ed. Essex: Mechaero Publishing.

Edgar, J. (2021*) A Century of Car Aerodynamics: The Science and Art of Cars and Airflow.* Independently Published.

Edgar, J. (2022) *Modifying the Aerodynamics of Your Road Car.* Dorset: Veloce Publishing Ltd.

Forbes, T., Jackson, A. and Smith, S. (2022) *Fundamentals of Automotive Aerodynamics.* London: Routledge.

Hucho, W. (2013) *Aerodynamics of Road Vehicles: From Fluid Mechanics to Vehicle Engineering.* 5th Ed. London: Elsevier.

Katz, J. (2021) *Automotive Aerodynamics*. 2nd Ed. Hoboken, NJ: Wiley.

Newey, A. (2017) *How to Build a Car.* London: Harper Collins.

Pope, A. (2011) *Basic Wing and Airfoil Theory.* 2nd Ed. Whitefish, MT: Literary Licencing.

Turner, J. (2023) *Vehicle Aerodynamics and Air Management.* Oxford: Elsevier.

White, F.M. (2023) *Fluid Mechanics for Automotive Applications.* New York: McGraw Hill Education.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Harish, V. (2020) 'An aerodynamic assessment of vehicle-side wall interaction using numerical simulations', *International Journal of Automotive and Mechanical Engineering*, Volume 17, Issue 1, 7587−7598.
https://www.researchgate.net/publication/340255801_An_Aerodynamic_Assessment_of_Vehicle-Side_Wall_Interaction_using_Numerical_Simulations

Xiaoyan, Y., Qing, J., Di, B. and Zhigang, Y. (2018) 'A comparative study of different wheel rotating simulation methods in automotive aerodynamics'. SAE *Technical Paper*, Volume 15.
https://www.researchgate.net/publication/358366578_Comprehensive_Study_of_the_Aerodynamic_Influence_of_Ground_and_Wheel_States_on_the_Notchback_DrivAer

Links

This unit links to the following related units:

Unit 4011: Fluid Mechanics

Unit 4093: Race Car Design and Manufacturing

Unit 4094: Motorsport Workshop Practices

Unit 5004: Computational Modelling in Virtual Engineering

Unit 5023: Thermofluids

Unit 5062: Engine and Vehicle Design Performance

Unit 5070: Further Motorcycle Engineering

Unit 5060: Motorsport Workshop Preparation and Inspection

Unit Code: D/651/3076

Level: 5

Credits: 15

Introduction

Motorsport vehicles operate in the harshest of environments and physical condition, across sustained periods of time. It is essential that such vehicles are meticulously maintained, prepared and developed to ensure success in motorsport events. Building upon the foundational knowledge and skills acquired in the *Motorsport Workshop Practices* unit, this unit takes a deeper dive into the intricacies of motorsport vehicle set-up, development and inspection, preparing participants to excel in the competitive world of motorsport engineering.

The aim of this unit is to enable students to explore advanced techniques and strategies for motorsport vehicle set-up and development, focusing on harnessing driver feedback and data analysis to optimise the performance and handling characteristics of motorsport vehicles. From fine-tuning suspension geometry to optimising aerodynamics, and from adjusting vehicle balance to maximising traction, this unit equips students with the knowledge and skills necessary to achieve peak performance on the track.

Topics include: comprehensive pre-race inspections; interpretation and analysis of data from on-board telemetry systems; lap-timing software analysis; driver feedback and how to translate this to motorsport vehicle performance; and inspection techniques for detecting wear and fatigue in motorsport vehicle components, including crack testing, non-destructive testing methods, and advanced metallurgical analysis.

On successful completion of this unit, students will have acquired an advanced understanding of motorsport vehicle set-up and development techniques, with proficiency in high-end inspection methods for detecting wear and fatigue in motorsport vehicle components. Students will make critical decisions and maintain high standards of performance and reliability in motorsport engineering.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Optimise vehicle performance by developing skills in motorsport vehicle set-up and development

LO2 Utilise data analysis techniques to optimise motorsport vehicle performance and minimise lap times, to gain a competitive edge in motorsport competitions

LO3 Demonstrate the ability to conduct comprehensive inspections of motorsport vehicle components and potential issues to ensure the reliability and safety of motorsport vehicles for competition

LO4 Demonstrate preparation, inspection practices and adherence to higher standards of performance and reliability in motorsport engineering.

Essential Content

LO1 **Optimise vehicle performance by developing skills in motorsport vehicle set-up and development**

Driver feedback:

Data-logging channels and creation of mathematical channels for driver feedback

Creation of appropriate workbooks with the inclusion of appropriate channels focusing solely on driver operation

Driver's feedback, and the analysis of qualitative and quantitative track data.

Analysis techniques:

Analysis of data to interpret driver standards and lap times

Video synching and analysis to support driver-training techniques

Performance: analysis of data collected to determine recommended actions to improve driver performance

Performance reporting to a driver: presentation and explanation of decisions made due to review of data and vehicle performance compared with driver preference.

LO2 **Utilise data analysis techniques to optimise motorsport vehicle performance and minimise lap times, to gain a competitive edge in motorsport competitions**

Data acquisition:

Sensors and actuators for an advance data-logging system including pito tube, aero sensors and tyre temperatures and pressures

Data from a plethora of sources including vehicle and engine logged data, time, timekeepers, timing systems, engineers' reports, weather reports etc.

Use of relevant computer-based software systems or packages, applications and limitations, such as data analytics, databases and computer-aided design (CAD).

Data analysis:

Evaluation of vehicle and driver performance

Comparisons and compromises to vehicle performance set-ups to driver preference

Detailed analysis of data to make informed decisions on vehicle set-up

Performance reporting to engineers: presentation and explanation of decisions made due to review of data and how to improve vehicle performance

User created maths channels to create detailed data for advanced analysis.

LO3 **Demonstrate the ability to conduct comprehensive inspections of motorsport vehicle components and potential issues to ensure the reliability and safety of motorsport vehicles for competition**

Non-destructive testing (NDT):

Knowledge of ultrasonic testing to detect internal flaws or defects in materials, such as cracks or voids, without damaging the material

Magnetic particle testing for defects in ferrous materials by applying a magnetic field and then observing the formation of magnetic particles around defects

Knowledge of penetrant testing – applying a liquid dye penetrant to the surface of a material, allowing it to seep into surface-breaking defects, which are then revealed by applying a developer

Knowledge of eddy-current testing using electromagnetic induction to detect surface and sub-surface flaws in conductive materials, such as cracks or corrosion.

Metallurgical analysis:

Microscopic examination: optical or electron microscopes to examine the microstructure of metal components, revealing details such as grain size, inclusion content and phase distribution

Hardness testing: measuring the resistance of a material to indentation or scratching, providing insights into its mechanical properties and potential susceptibility to wear or deformation

Chemical analysis: determine the elemental composition of metal samples through techniques such as spectroscopy or wet chemical methods, helping to identify alloy composition and potential impurities.

Advanced imaging and measurement equipment:

3D laser scanning: precise 3D measurements of motorsport vehicle components and assemblies, which allows accurate dimensional analysis and reverse engineering

Coordinate measuring machines: utilising touch probes or optical sensors to measure the geometric features of components with high accuracy, ensuring dimensional conformity and alignment

Thermal imaging and sensors: detecting variations in temperature across motorsport vehicle components, to identify areas of potential overheating or abnormal thermal behaviour.

Industry 4.0 in motorsport:

Concepts, usage and integration: impact on an organisation and the sector including the integration of automation, digital systems and manufacturing engineering systems.

LO4 **Demonstrate preparation, inspection practices and adherence to higher standards of performance and reliability in motorsport engineering**

Advanced inspection techniques:

Strain gauge analysis: measuring the deformation or strain experienced by motorsport vehicle components under load, providing insights into structural integrity and performance characteristics

Data-logging systems: capturing real-time performance data from various sensors installed on the motorsport vehicle, which allows engineers to monitor critical parameters such as temperature, pressure, vibration and displacement during testing and competition

Processes for minimising the risk of mechanical failures.

Decision processes for changing or 'lifting' of components:

Meticulous checking, inspection, maintenance and preparation of a motorsport vehicle

Maintaining and updating lifespan documentation of motorsport vehicles determined from inspections, data analysis and testing

Presentation of documentation, reports and history of a motorsport vehicle

Processes and decision-making to maximise success on the track.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Optimise vehicle performance by developing skills in motorsport vehicle set-up and development</td><td rowspan="5">LO1 and LO2

D1 Evaluate improvements in motorsport vehicle performance across several motorsport events, effectively reporting all decisions with justifications and deep-data analysis.</td></tr>
<tr><td>P1 Develop skills in assessing driver performance through analysis of data streams and video recording.

P2 Optimise driver performance gains and areas for improvement.</td><td>M1 Present in appropriate terminology how a driver can improve their lap times.</td></tr>
<tr><td colspan="2">LO2 Utilise data analysis techniques to optimise motorsport vehicle performance and minimise lap times, to gain a competitive edge in motorsport competitions</td></tr>
<tr><td>P3 Determine appropriate sensors to enable detailed analysis of motorsport vehicle dynamics and behaviour.

P4 Utilise data from credible sources to create several maths channels to improve motorsport vehicle handling and performance.</td><td>M2 Monitor the decisions made to justify substantiate lap time reductions.</td></tr>
</table>

Pass	Merit	Distinction
LO3 Demonstrate the ability to conduct comprehensive inspections of motorsport vehicle components and potential issues to ensure the reliability and safety of motorsport vehicles for competition		**LO3 and LO4**
P5 Determine suitability of imaging and measuring equipment for motorsport vehicle components. **P6** Demonstrate advanced inspection techniques for motorsport vehicle components.	**M3** Analyse working cycles, typical failures, and appropriate processes to ensure lifespans of components.	**D2** Produce a complete set of technical data and present findings appropriately to ensure a motorsport vehicle maintains safety, reliability and performance for a motorsport season.
LO4 Demonstrate preparation, inspection practices and adherence to higher standards of performance and reliability in motorsport engineering		
P7 Demonstrate appropriate inspection techniques within a motorsport vehicle workshop to test components. **P8** Utilise live data to monitor vehicle health and condition during a motorsport event.	**M4** Carry out complete maintenance, inspection, and repair of a motorsport vehicle prior to a motorsport event.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Brown, C. (2011) *Making Sense of Squiggly Lines.* London: Kimberley Media Group.

Vitali, I. et al. (2022) *Physical Metallurgy: Metals, Alloys, Phase Transformations.* Berlin: De Gruyter.

Wong, B.S. (2014) *Non-Destructive Testing – Theory, Practice and Industrial Applications.* London: Lambert Academic Publishing.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Misokefalou, E., Papoutsidakis, M. and Priniotakis, G. (2022) 'Non-destructive testing for quality control in automotive industry', *International Journal of Engineering Applied Sciences and Technology*, 7, pp. 349–355.

Links

This unit links to the following related units:

Unit 4092: Vehicle Dynamics and Performance

Unit 4093: Race Car Design and Manufacturing

Unit 4094: Motorsport Workshop Practices

Unit 4112: Vehicle Repair and Diagnostics

Unit 5059: Automotive Aerodynamics

Unit 5062: Engine and Vehicle Design Performance

Unit 5070: Further Motorcycle Engineering

Unit 5061: Automotive Incident Investigation

Unit Code: F/651/3077

Level: 5

Credits: 15

Introduction

Since the dawn of motoring, vehicles have transformed mobility and connected worlds, yet not without cost. Road accidents remain a stark reality of automotive transport, with each incident representing a complex interplay of factors that demand meticulous analysis. This unfortunate inevitability often spurs improvements in road safety, influencing both policy and design. Professionals with critical forensic skills are needed to dissect these events, identifying contributory elements from mechanical failures to human error. As technologies evolve and automated and autonomous vehicles enter the mainstream, the sector faces new challenges and opportunities. Skilled investigators are increasingly essential, working alongside major industry players to enhance safety standards and reduce future incidents, making this field rich with career potential. Collision investigation would be part of the job role of members of the police service, private sector investigators or as team members for research and development projects related to road and vehicle safety.

This unit introduces students to the approaches that are taken to incident and collision investigations. The topics cover the stages of accident investigations, from roadside examination, through laboratory- and workshop-based investigations to how the results of investigations can influence safe design of vehicles and highways.

Topics included are: incident and collision site investigation; physical evidence collection; vehicle inspection; on-board vehicle data recorders; incident and collision reconstruction; and vehicle safety systems.

On successful completion of this unit, students will be able to describe the activities that are carried out during incident and collision investigations, and how the results of investigations are analysed and assessed. They will explore how incident and collision investigations can improve road safety for vehicle users and pedestrians.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine site investigation activities that are carried out following an automotive incident

LO2 Explore the procedures used to examine vehicles following an automotive incident

LO3 Assess how evidence captured following an automotive incident can be interpreted to determine the cause

LO4 Analyse how incident investigations can improve safety for road users.

Essential Content

LO1 **Examine site investigation activities that are carried out following an automotive incident**

Overview:

Past, present, and future advancements

Automotive incident types: accidents (collisions, single-vehicle accidents), mechanical failures, electrical failures, tyre issues, software failures, environmental incidents, driver-related incidents

Global standards for incident investigation (e.g. International Labor Organisation (ILO) and International Standards Organisation (ISO))

Role of regulatory bodies (e.g. National Transportation Safety Board (NTSB) in the USA, the Health and safety Executive (HSE) in the UK)

Use of incident/collision investigation techniques (e.g. root cause analysis (RCA), the 5-Whys, failure mode and effects analysis (FMEA)

Practical problem solving (PPS))

Models for road safety: Haddon matrix, Swiss cheese model

EuroNCAP: safe driving, crash avoidance, crash mitigation, post-crash

Cultural and legal implications, preventative measures and safety recommendations, case studies and real-world applications

Sequences of a traffic collision: normal driving, incident-phase, pre-crash-phase, in-crash-phase, post-crash-phase.

Initial site investigation and management:

Securing the site of the incident/collision

Preservation of the scene for investigation

Involvement of emergency services: fire, police, ambulance

Initial risk assessment of hazards that remain on-site

Recording of locations of vehicles and other debris

Recording of time, date and weather information

Recording of vehicle conditions: scrapes, cuffs, tyre condition, other damage

Procedures for dealing with electric vehicles: HV disconnect; ensuring the vehicle is safe; checks for deformation penetration of the battery pack.

Photographic evidence collection:

Capturing of the overall scene from a range of angles

Location of vehicles

Street furniture

Debris

Skid marks and other notable markings

Road layout and markings

Condition of road surface.

Physical evidence collection:

Mapping the location

Taking measurements of locations of vehicles

Collection of debris, vehicle parts, paint chips, fluids

Collection of statements from those involved and other witnesses

Collection of fingerprints

Castings of tyre tracks.

Use of digital tools:

Examples include 3D laser scanning (Faro Focus, Leica RTC360), drones (i.e. unmanned aerial vehicles (UAVs) such as DJI Phantom 4 Pro, DJI Mavic Air 2), photogrammetry (e.g. Agile Metashape, Autodesk ReCap), GPS and geographic information systems (GIS) (e.g. Trimble GPS, ArcGIS), simulation software (e.g. PC-Crash, human vehicle environment (HVE)), mobile data extraction (e.g. Berla iVe, Cellebrite UFED), digital documentation tools (e.g. Adobe, Microsoft)

Vehicle-based scene surveys: recording of bend radii; road cambers; longitudinal slopes, effect on lateral acceleration; pitch, roll, yaw over bumps.

LO2 **Explore the procedures used to examine vehicles following an automotive incident**

Vehicle inspections:

Mechanical inspection for defects and failures

Assessment of damage patterns and scale

Recording of types and severity of damage

Condition of vehicle: lighting, field of vision, ergonomics of controls, condition of the interior, tyres and braking systems.

Use of on-board vehicle data recorders:

Analysis of data retrieved from on-board event data recorders: data storage system for automated driving (DSSAD); telematics; CCTV; dashcams

Types of data: speed, braking, vehicle manoeuvres, driver inputs

Driver and passenger data.

LO3 **Assess how evidence captured following an automotive incident can be interpreted to determine the cause**

Incident reconstruction:

Reconstruction of the scene of the incident/collision

Analysis of vehicle dynamics

Identification of the causes of collisions and different types of incidents

Tests: skid, sled and projectile

Reconstruction of incidents (e.g. collision); scene pro tool

Behaviour of different types of vehicles: cars, motorcycles, LGVs, agricultural vehicles, buses

Computer simulations.

Contributing factors:

Road-user behaviour

Road layout and design

Road surface condition

Signage

Intelligent transport systems

Weather and environmental conditions.

LO4 **Analyse how incident investigations can improve safety for road users**

Approaches to implementing safety policies:

What safety problems need to be addressed?

What solutions are available?

Do existing solutions work?

What is the best was to get effective solutions to the market?

Implementation of solutions: regulations, policies, test procedures

Post implementation monitoring.

Vehicle safety systems:

Collision avoidance systems

Active and passive safety systems

Advanced driver assistance systems (ADAS)

Autonomous emergency braking (AEB) system

Vehicle design features

Passenger safety systems.

Infrastructure design:

Road layout

Infrastructure: lighting, traffic calming, surface drainage

Provision for pedestrians and other road users.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine site investigation activities that are carried out following an automotive incident		
P1 Discuss the approaches that can be followed when securing and initially investigating the scene of a collision. **P2** Explain the importance of collecting photographic evidence following a collision. **P3** Examine the types of physical evidence that can be collected from a collision location and the methods used to collect it.	**M1** Assess the approaches that are taken to collect information from the scene of a collision and the reasons for following them.	**D1** Evaluate the effectiveness of traditional and digital incident site investigation techniques (for a given road traffic collision scenario).
LO2 Explore the procedures used to examine vehicles following an automotive incident		
P4 Assess the importance of carrying out vehicle inspections following an automotive collision. **P5** Explore the benefits of interpreting data from on-board data recorders following an automotive collision.	**M2** Review the use of vehicle inspections and data analysis when investigating automotive collisions.	**D2** Evaluate the interaction between physical vehicle examinations and analysis of data in determining the cause of an automotive collision.

Pass	Merit	Distinction
LO3 Assess how evidence captured following an automotive incident can be interpreted to determine the cause		
P6 Assess how reconstructing an incident scene can identify the root cause of a road traffic collision. **P7** Discuss the factors that contribute to road traffic collisions and how they interrelate.	**M3** Assess how the cause of a collision can be determined through the use of simulations and an assessment of contributing factors.	**D3** Evaluate the use of reconstructions to determine the root cause of road traffic collisions.
LO4 Analyse how incident investigations can improve safety for road users		
P8 Analyse the use of collision investigations as a method of improving the safety of road vehicles. **P9** Discuss how collision investigations can improve safety for all road users.	**M4** Assess how collision investigations can lead to safety improvements for drivers, passengers and other road users.	**D4** Evaluate the benefits and challenges associated with collision investigations with respect to the safety of drivers, passengers and other road users.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Burg, H. and Burg, W. (2020) *Automotive Accident Reconstruction: Practices and Principles.* 2nd Ed. New York: Springer.

Graham, I. (2014) *Forces and Motion: Investigating a Car Crash.* Raintree.

Harris, D. (2019) *Crash Course in Accident Investigation and Reconstruction.* Boca Raton: CRC Press.

Rivers, R. (2006) *Evidence in Traffic Crash Investigation and Reconstruction*. Charles C Thomas Publisher.

Stevens, F. (2024) *The Anatomy of a Crash: Insights from Traffic Accident Investigations*. Stevens.

Watts, A. (2018) *Traffic Accident Investigation Manual*. 3rd Ed. Evanston, IL: Northwestern University Press.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Accident Analysis & Prevention. Available at: https://www.journals.elsevier.com/accident-analysis-and-prevention.

Automotive Safety Research. Available at: https://www.automotivesafetyresearch.com/.

Good Practice in Forensic Road Collision Investigation. Available at: https://www.itai.org/goodpracticeinforensicroadcollisioninvestigation.pdf.

International Journal of Automotive Technology and Management. Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijatm.

International Journal of Crashworthiness. Available at: https://www.tandfonline.com/toc/tcrs20/current.

International Journal of Electric and Hybrid Vehicles. Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijehv.

Journal of Accident Investigation. Available at: https://www.accidentinvestigationjournal.com/.

Journal of Crash Analysis. Available at: https://www.crashanalysisjournal.com/.

Crispus Musingura, Gunwoo Lee and YongHan Ahn 'Mitigating road traffic crashes in urban environments: a case study and literature review-based approach', *ResearchGate*. Available at: https://www.researchgate.net/publication/331236773_Mitigating_Road_Traffic_Crashes_in_Urban_Environments_A_Case_Study_and_Literature_Review-based_Approach.

Website articles

(2019) *Models and Methods for Collision Analysis.* Available at: https://www.racfoundation.org/wp-content/uploads/Models_and_methods_for_collision_analysis_Stanton_March_2019.pdf.

Motor Transport. Reed Business Information. Available at: https://www.motortransport.co.uk/.

Road Accident Investigation. SpringerLink. Available at: https://link.springer.com/book/10.1007/978-3-030-40348-1.

(2014) 'The new in-depth, at-the-scene, accident investigation database in India', *IRCobi*. Available at: https://www.ircobi.org/new-accident-investigation-database-in-india.

Links

This unit links to the following related units:

Unit 4093: Race Car Design and Manufacturing

Unit 4094: Motorsport Workshop Practices

Unit 4096: Automotive Workshop Practices

Unit 4097: Electric Vehicle Battery Manufacture

Unit 5069: Vehicle Systems and Technology

Unit 5062: Engine and Vehicle Design Performance

Unit Code: H/651/3078

Level: 5

Credits: 15

Introduction

Engine and vehicle design careers focus on advancing the performance, efficiency and sustainability of vehicles. This field involves meticulous planning and advanced technology to enhance everything from fuel consumption to emissions standards, ensuring that vehicles meet rigorous regulatory requirements while satisfying consumer demands for speed and power. Despite emerging alternatives, the combustion engine remains prevalent, supported by its established infrastructure and technological refinements enhancing its efficiency and environmental compliance. Current trends include improving vehicle engines through advanced combustion techniques and hybrid technologies, which combine electric and conventional engines for better fuel economy and reduced emissions. Looking ahead, the industry is exploring more innovations such as fully electric powertrains and hydrogen fuel cells, alongside advancements in autonomous driving and AI integration, which promise to redefine vehicle performance and user interaction in the coming decades. Innovations in materials science also play a key role, with lighter and stronger materials leading to better fuel efficiency and performance.

The aim of this unit is to enable students to learn advanced concepts in engine design and explore the intricacies of engine design, use of simulation techniques and practical aspects of vehicle dynamics for optimal performance on the road or track.

Among the topics taught in this unit are: simulation and 1D software tools to model and analyse engine performance under various operating conditions; rapid prototyping and optimisation of engine designs; impact of vehicle design factors such as weight distribution, body shapes and engine layouts on overall vehicle performance, handling, and fuel efficiency; integration of engine and vehicle design principles to achieve harmonious performance characteristics, to ensure that engines are optimised to complement the vehicle's dynamics and driving characteristics; and balance power, torque and responsiveness with considerations such as emissions, fuel economy and drivability to create vehicles that excel in real-world driving scenarios.

On successful completion of this unit, students will be able to design, analyse and enhance internal combustion engines both in simulated and practical environments.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Demonstrate proficiency in engine design principles to optimise engine performance, efficiency and reliability

LO2 Analyse the relationship between engine characteristics and vehicle dynamics to optimise overall vehicle performance and drivability

LO3 Utilise simulation and 1D software tools to model and analyse engine performance under various operating conditions

LO4 Integrate theoretical knowledge with practical skills to design, simulate and optimise engines and vehicles for peak performance and efficiency.

Essential Content

LO1 **Demonstrate proficiency in engine design principles to optimise engine performance, efficiency and reliability**

Thermodynamics and fluid mechanics:

Flow of fluid, head losses due to sudden restriction, enlargement of pipe entrance/exit

Reynolds number: inertia and viscous resistance forces, laminar and turbulent flow, critical velocities, air flow and rarefaction

Thermodynamic systems: polytropic processes; general equation of pressure and volume; relationships between index 'n' and heat transfer during a process; constant pressure and reversible isothermal and adiabatic processes

Closed systems, open systems, application of first law to derive system energy equations

Study of the thermodynamics of internal combustion engines

Second law of thermodynamics: statement of law, schematic representation of a heat engine to show heat and work flow

Heat engine cycles: Carnot cycle, Otto cycle, diesel cycle, dual combustion cycle, Joule cycle; property diagrams, Carnot efficiency.

Combustion:

Performance characteristics: engine trials, mean effective pressure, indicated and brake power, indicated and brake thermal efficiency, specific fuel consumption, heat balance and volumetric efficiency; air standard efficiency

Fuel types including diesel, gasoline and synthetic (e.g. hydrogen, hydrocarbons)

Flame travel, pre-ignition and detonation and the properties of fuels: octane rating, cetane rating, flash point, fire point and volatility

Combustion process for spark ignition and compression ignition engines and the by-products of combustion for different engine conditions and fuel mixtures

Induction swirl, directed straight port, deflector wall port, masked valve port and helical port

Flame propagation, intensity of detonation, controlled and uncontrolled combustion, including cause and effects both in pre and post-ignition

Tumble versus swirl

Air flow due to port and piston design

Homogenous and stratified charge.

Mechanical systems:

Valve lead, lag and overlap reviewing methods used to improve volumetric efficiency

Improvements to engine efficiency and performance via variable valve timing, variable valve lift, cylinder deactivation, turbocharging, supercharging and intercoolers

Multi-valve arrangements, components, operation and drive arrangements.

LO2 **Analyse the relationship between engine characteristics and vehicle dynamics to optimise overall vehicle performance and drivability.**

Vehicle dynamics:

Engine configuration and placement and impact on vehicle weight distribution

Mathematical formula to compare power and torque to vehicle acceleration

Gear and engine speed matching to optimise acceleration

Aerodynamic optimisation to reduce drag and allow improved vehicle fuel efficiency.

Engine characteristics:

Compression ratios, crankshaft design, conrod ratios, camshaft lift and piston design to ensure appropriate operation of engine design

Component interaction

3D models to ensure component clash is avoided

Fuel flow and engine maps to allow performance and emission standards during various engine cycles, emission drive cycles and acceleration tests

ECU main maps and compensation maps: fuel, ignition and lambda; TPS versus speed, ignition compensation map, dwell timing, target lambda, adaptive fuel maps, lambda control and boost/manifold pressure maps, fuel injection timing, fuel rail pressure maps and also the function of EMS with regards to data logging and histograms.

LO3 **Utilise simulation and 1D software tools to model and analyse engine performance under various operating conditions**

Mathematical modelling:

Mathematical formulae: induction and exhaust system harmonics, reflection, and rarefaction, how to determine correct engine size, intake and exhaust duct diameters and lengths, intake and exhaust valve and throat sizes, and calculations to determine correct valve train dynamics, air flow and fuel supply

Engine design and complete mathematical calculations for component motion, size and architecture to allow a 1D simulation model to be created.

Simulation:

1D engine simulation software, development of one- and multi-cylinder engines, the conversion of mathematical design into virtual engine simulation and post-processing to determine faults and areas for development

Engine development for drive cycles, emissions or performance.

LO4 **Integrate theoretical knowledge with practical skills to design, simulate, and optimise engines and vehicles for peak performance and efficiency**

Decision-based optimisation:

Simulation optimisation for intake and exhaust lengths, valve sizes, cam timing, turbocharger sizing

Bore and stroke optimisation for peak engine RPM, torque and power

Post-processing of simulation results to identify areas of improvement, weaknesses in engine configuration or design

Present findings to a high technical standard and justify improvement paths.

Practical testing:

Engine dynamometer testing: principles of map-able engine management systems, connection of EMS to engine to include requirements of advanced wiring harness, sensors and actuators, and also connection of EMS to PC and implementation of map-able EMS

Basic engine set-up, soft and hard engine speed limiters, speed index mapping, throttle position limit and default set-up and engine sensor and actuator set-up

Improvements to maps to meet specific driving criteria

Flow bench testing: use of rapid prototyping and rapid manufacture to physically test enhancements or components in a timely and cost-effective manner including single- and multi-cylinder testing, intake and exhaust flow.

Validation:

Validate simulation models from experimental and test data and through the use of empirical and measured data to ensure accurate fully validated simulation models

Critical analysis of measured and simulated data to determine research and development paths and ensure that improvements and targets have been achieved.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Demonstrate proficiency in engine design principles to optimise engine performance, efficiency and reliability		**LO1 and LO2**
P1 Demonstrate knowledge in polytropic processes and the relationships between system constants for an ideal gas. **P2** Apply the first and second law of thermodynamics to automotive engines.	**M1** Determine improvements to the mechanical and thermal efficiencies of IC power units.	**D1** Analyse mapping configurations to enable emission-compliant and high-performance engine output.
LO2 Analyse the relationship between engine characteristics and vehicle dynamics to optimise overall vehicle performance and drivability		
P3 Analyse calculations performed on power and torque profiles for various engine configurations and acceleration targets. **P4** Calculate engine speed and gear shift profiles for various drive cycles.	**M2** Investigate component designs and layouts for effective mechanical interaction.	

Pass	Merit	Distinction
LO3 Utilise simulation and 1D software tools to model and analyse engine performance under various operating conditions		**LO3 and LO4**
P5 Calculate all appropriate engine architecture to enable transposition into an industry standard engine simulation programme. **P6** Utilise industry standard software to design a fully functional internal combustion engine.	**M3** Analyse simulation test data to identify system features and abnormal combustion.	**D2** Determine appropriate performance-development paths and present pre- and post-test results in a technical manner.
LO4 Integrate theoretical knowledge with practical skills to design, simulate and optimise engines and vehicles for peak performance and efficiency		
P7 Integrate maps into engine management systems for appropriate running of engines. **P8** Analyse results from various flow bench tests.	**M4** Examine measured data and identify the effects of abnormal engine operation.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Balkwill, J. (2018) *Performance Vehicle Dynamics: Engineering and Applications.* Oxford: Butterworth-Heinemann.

Bosch, R. (2022) *Automotive Handbook*. Germany: Wiley.

Bryden, K., Ragland, K.W. and Kong, S.C (2022) *Combustion Engineering.* 3rd Ed. Oxon: Routledge.

Burgess, P. and Gollan, D. (2015) *How to Build, Modify & Power Tune Cylinder Heads.* United Kingdom: Veloce Publishing.

Denton, T. and Pells, H. (2023) *Automobile Mechanical and Electrical Systems*. 3rd Ed. Abingdon: Routledge.

Ferrari, G., Onorati, A. and D'Errico, G. (2022) *Internal Combustion Engines*. Italy: Società Editrice Esculapio.

Gillespie, T.D. (2021) *Fundamentals of Vehicle Dynamics.* Revised Ed. Warrendale: SAE International.

Guzzella, L. and Sciarretta, A. (2013) *Vehicle Propulsion Systems: Introduction to Modeling and Optimization.* 3rd Ed. Berlin: Springer.

Heisler, H. (2011) *Advanced Vehicle Technology*. 2nd Ed. Oxford: Butterworth-Heinemann.

Heywood, J. (2018) *Internal Combustion Engine Fundamentals.* 2nd Ed. USA: McGraw Hill LLC.

Hillier, V.A.W. and Coombes, P. (2014) *Hillier's Fundamentals of Motor Vehicle Technology.* 6th Ed. Cheltenham: Nelson Thornes.

Livesey, A. (2019) *Practical Motorsport Engineering.* Oxon: Routledge.

Mavropoulos, G., Andritsakis, E.C. and Papagiannakis, R.G. (2023) *Internal Combustion Engine Performance. Special Issue of Energies.* Available at: https://www.mdpi.com/journal/energies/special_issues/Internal_Combustion_Engine_Performance_2023:citation[oaicite:0]{index=0}.

Pulkrabek, W. (2014) *Engineering Fundamentals of the Internal Combustion Engine.* 2nd Ed. Pearson Education.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Leach, F. (2023) 'A negative emission internal combustion engine vehicle', *Atmospheric Environment,* 294, pp. 1–7.

Martins, J. and Brito, F.P. (2020) 'Alternative fuels for internal combustion engines', *Energies,* 13(16), pp. 1–33.

Smith, J.K., Roberts, P., Kountouriotis, A., Richardson, D., Aleiferis, P. and Ruprecht, D. (2020) 'Thermodynamic modelling of a stratified charge spark ignition engine', *International Journal of Engine Research*, 21(5), pp. 801–810.

Links

This unit links to the following related units:

Unit 4112: Vehicle Repair and Diagnostics

Unit 4094: Motorsport Workshop Practices

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit Code: J/651/3079

Level: 5

Credits: 15

Introduction

Advanced hybrid and electric vehicle technologies are spearheading the automotive industry's shift towards more sustainable and economically viable transportation. These technologies are evolving rapidly, driven by significant advancements in high-voltage systems, battery efficiency and powertrain innovations that enhance vehicle performance while extending driving ranges. The trend towards electrification addresses both environmental concerns and economic challenges, by reducing reliance on fossil fuels. However, this shift reveals considerable skill gaps, necessitating new roles such as high-voltage system specialists, battery engineers and EV system designers, which are essential for developing and deploying these cutting-edge technologies.

The aim of this unit is to impart a comprehensive understanding of the design, functionality and manufacturing of high-voltage systems. This unit delves deeply into the crucial aspects of the industry, with a particular emphasis on battery technologies and the production of high-voltage systems. It aligns with current and emerging safety standards and legislation, ensuring a thorough grasp of the key elements essential for professionals in this rapidly evolving field.

Topics included are: high-voltage vehicle systems focusing on legislation, responsibilities, and health and safety regulations; architecture of electrical distribution systems including how these are created and how communication is managed; the design of diagnostic systems for fault detection in hybrid and electric vehicles in terms of software and hardware; and the intricacies of battery manufacturing and assembly with regards to working protocols and work environments.

Upon successful completion, students will possess a deep understanding of the theoretical, practical and technical aspects of the hybrid and electric automotive industry. They will be adept at analysing, interpreting and evaluating information to design and manage high-voltage systems within these vehicles, considering the required manufacturing environments.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Evaluate use cases directly relevant to design safety standards, regulation and working practices in regards to hybrid and electric vehicles

LO2 Investigate the constructional and communicational requirements of electrical distribution systems

LO3 Determine electric vehicle diagnostic architecture to support customer and factory diagnostic functions

LO4 Evaluate motor and battery technology and architecture for hybrid and electric vehicles to meet associated manufacturing system requirements.

Essential Content

LO1 **Evaluate use cases directly relevant to design safety standards, regulation and working practices in regards to hybrid and electric vehicles**

Automotive electric/hybrid vehicle safety, legislation and standards:

Review of safety issues relating to electric and hybrid vehicles and exploration of development of safety practices and vehicle safety designs in future vehicles

Electric and hybrid vehicles regulation

Electric and hybrid vehicles global technical standards (e.g. functional safety and ISO26262, cybersecurity and ISO 21434)

Advanced protection methods

IP rating

Requirements for the electric powertrain

Software and hardware controlled test

Electronic/electrical system and personal protection systems

Compliance including the risk assessment process, procedures and documentation used within the work area.

Safe working practices with automotive high-voltage systems and batteries:

Analysis and implementation of AC and DC current

Battery safety issues working on high-voltage electrical systems

Service disconnect

Battery connect and disconnect

Safety around the vehicle

Personal protective equipment (PPE)

Re-energising

Safety on EDS connections.

Advanced case studies:

Complex real-life industry case studies on automotive hybrid and electric vehicle systems and technologies specific to local region(s) and beyond.

LO2 **Investigate the constructional and communicational requirements of electrical distribution systems**

Electric vehicle high-voltage electrical distribution systems:

Earthing and grounding

Risk management
On-board diagnostics

Effective working practices, use/sharing of good practice

Electromagnetic compatibility

Noise control

Sensors.

Electrical distribution system architecture and communication:

Ingress protection

Cable design

Automotive and HV connectors

Cable glands, P-clips, wrap, tape and conduit

Cable fixings

Cable routing

EDS brackets

Cable protection

Ferrules/connectors and crimping

Current and cable thickness

Network communications: CAN, LIN and Wi-Fi systems, hexadecimal, binary communication; exploration, decoding, deciphering, diagnosis and writing of code for hierarchical communication techniques.

Teamwork and communications:

Present work undertaken relating to construction and communication requirements of electrical distribution systems to different audiences.

LO3 **Determine electric vehicle diagnostic architecture to support customer and factory diagnostic functions**

Engineering design of diagnostics systems for electric vehicles:

Vehicle quarantine area: advanced methods for isolating electrical faults, safe handling of vehicles in quarantine

Diagnostic tools applications in electric vehicle systems, integration with Internet of Things (IoT) for real-time monitoring and diagnostics

Technical service bulletins and recalls: case studies relating to the analysis of recent recalls and technical service bulletins, underlying causes and solutions implemented, compliance with regulatory standards and the impact of recalls on vehicle manufacturers

Software updates: over-the-air (OTA) updates including security concerns and version control; development and deployment of firmware updates in control modules

Limp-home mode: detailed study of implementing limp-home mode in various electric vehicle systems; analysis of real-world scenarios where limp-home mode is activated and the diagnostic processes involved

Diagnostic trouble codes (DTCs): techniques for analysing complex DTCs, including cross-referencing with multiple data sources; using machine learning to predict potential faults before they trigger DTCs

Wiring diagrams and symbols: interpretation of more complex wiring diagrams, including CAN bus and other network systems; using advanced electrical symbols in diagnostics

Schematic flowcharts: creating and interpreting flowcharts for entire vehicle systems rather than individual components

Permanent magnet synchronous motor/generator: control strategies for PMSM in electric vehicles, optimising the performance and efficiency of PMSMs

Control module software level: software architecture, real-time processing.

Diagnostics techniques for hybrid and electric vehicles:

Complex faults in a vehicle battery system including the design of battery protection systems and state of charge algorithms

Testing sensors, actuators and components

Fault diagnosis

Half-split method

CAN bus checks and tests

Parasitic draw

Six-stage procedure

Root cause analysis (RCA), advanced problem solving

Test plans and test documentation

Advanced industry case studies, diagnostics for complex problem solving.

LO4 **Evaluate motor and battery technology and architecture for hybrid and electric vehicles to meet associated manufacturing system requirements**

Motor units and drive:

Emotor architecture

Conventional rotor, stator and windings

Advancements in rotor and stators

Advancements in emotors including axial flux

Power control and voltage conversion: inverters and their construction and components

Control of the emotor.

Battery types and advancements in battery pack design:

Battery versus cell

Module versus pack

Pouch, prismatic and cylindrical

Double-sided coatings, advances in using materials for manufacturing batteries

Cell parameters: practical skills in battery inspection and sharing findings with the technical teams and managers.

Battery manufacturing systems:

Battery manufacturing process: advanced automation, application of lean manufacturing principles, supply chain management

Thermal management system: advanced cooling techniques, simulation and modelling, thermal runaway prevention

Final assembly and module end of line testing: automated testing systems, data analytics in testing, review industry standards and certifications for battery testing, such as ISO and UL standards

Pack assembly: modular design, advanced joining techniques, integration with vehicle systems, clean and dry rooms

Clean room standards: standards and classifications for clean rooms, such as ISO 14644, and their application in battery manufacturing; contamination control, PPE innovations including improvements in comfort and effectiveness

Air shower: efficiency and design; integration with clean room protocols

Prohibited materials: material compatibility, case studies of contamination incidents and their impact on battery performance and safety

Working protocols: standard operating procedures (SOPs), continuous improvement.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate use cases directly relevant to design safety standards, regulation and working practices in regards to hybrid and electric vehicles		
P1 Evaluate specific safety issues relating to batteries, particularly management of high voltage and current, fire, heating and overcharging for a given scenario. **P2** Interpret required legislation and standards to ensure compliance with specific responsibilities.	**M1** Demonstrate skills and knowledge of the specific safety issues at the battery system design level to meet appropriate safety and regulatory requirements.	**D1** Critically evaluate workplace related regulatory and safety compliance requirements for high-voltage systems, including live working, as required by a high voltage authorised person.
LO2 Investigate the constructional and communicational requirements of electrical distribution systems		
P3 Demonstrate safety, isolation, connection and grounding requirements for high-voltage electrical distribution systems. **P4** Determine the specific safety issues relating to electrical distribution systems and connectors, particularly management of high voltages involved. **P5** Investigate the constructional features and applications of electrical distribution systems.	**M2** Analyse the impact of relevant statutory regulations and organisational safety requirements on the constructional requirements of electrical systems.	**D2** Critically evaluate application of alternative communication language with regards to BUS systems for hybrid and electric vehicles.

Pass	Merit	Distinction
LO3 Determine electric vehicle diagnostic architecture to support customer and factory diagnostic functions		
P6 Demonstrate the ability to use diagnostics to troubleshoot and fix electric vehicle system or component faults in a customer or factory context. **P7** Evaluate specific uses of a variety of fault diagnostic tools for electric vehicles. **P8** Determine suitable test procedures from electric vehicle and diagnostic tool specifications.	**M3** Demonstrate how to support the creation of diagnostic structures to support customer and factory diagnostic functions.	**D3** Produce industry standard documentation as a follow up to undertaking critical analysis of the test plans for failures or inadequacies in electric vehicle systems and components.
LO4 Evaluate motor and battery technology and architecture for hybrid and electric vehicles to meet associated manufacturing system requirements		
P9 Evaluate current processes of making a lithium-ion battery in line with the manufacturing system requirements. **P10** Evaluate advances in motor and battery technology and materials.	**M4** Demonstrate deeper knowledge of the processes involved in the manufacturing of motors and batteries.	**D4** Design a battery manufacturing and assembly factory with necessary procurement requirements and specific considerations to ensure functional efficiency and safety compliance.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Chan, C.C., Chau, K.T. and Jiang J.Z. (2022) *Modern Electric Vehicle Technology.* 2nd Ed. Oxford: Oxford University Press.

Denton, T. (2020) *Electric and Hybrid Vehicles*. 2nd Ed. Oxon: Routledge.

Ehsani, M., Gao, Y. and Emadi, A. (2021) *Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals, Theory, and Design.* 4th Ed. Boca Raton, FL: CRC Press.

Emadi, A. (2021) *Advanced Electric Drive Vehicles.* 2nd Ed. Boca Raton, FL: CRC Press.

Husain, I. (2021) *Electric and Hybrid Vehicles: Design Fundamentals*. 3rd Ed. Oxon: CRC Press.

Larminie, J. and Lowry, J. (2012) *Electric Vehicle Technology Explained.* 2nd Ed. Chichester: Wiley.

Pistoia, G., Liaw, B. and Kang, J. (2021) *Battery Technology and Applications.* 3rd Ed. Amsterdam: Elsevier.

Quarto, M. and Goodnight, N. (2022) *Light Duty Hybrid and Electric Vehicles (Master Automotive Technician)*. Massachusetts: Jones & Bartlett Publishers.

eBooks

Mavropoulos, G., Andritsakis, E.C. and Papagiannakis, R.G. (2023*) Internal Combustion Engine Performance. Special Issue of Energies*. Available at: https://www.mdpi.com/journal/energies/special_issues/Internal_Combustion_Engine_Performance_2023.

Pistoia, G. (2010) *Electric and Hybrid Vehicles: Power Sources, Models, Sustainability, Infrastructure and the Market*. Available at: https://www.perlego.com/book/1836150/electric-and-hybrid-vehicles-power-sources-models-sustainability-infrastructure-and-the-market-pdf?utm_source=google&utm_medium=cpc&campaignid=15781033413&adgroupid=134828831507&gclid=CjwKCAiAuOieBhAIEiwAgjCvcuCu3XRkum0sntnT1G9gkQ8nw3QlHuOirnReSYl3KL0xd26w6avHTBoClxMQAvD_BwE.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Sanguesa, J.A., Torres-Sanz, V., Garrido, P., Martinez, F.J. and Marquez-Barja, J.M. (2021) 'A review on electric vehicles: Technologies and challenges', *Smart Cities*, 4, pp. 372–404.

Shao-Chao, M., Jin-Hua, X. and Ying, F. (2022) 'Characteristics and key trends of global electric vehicle technology development: A multi-method patent analysis', *Journal of Cleaner Production,* 338.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4097: Electric Vehicle Battery Manufacture

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 5064: Further Industrial Digitalisation Technologies for Engineers

Unit Code: M/651/3080

Level: 5

Credits: 15

Introduction

The engineering industry continues to evolve rapidly and staying abreast of technological advances is crucial for ensuring business success and competitiveness. The advent of Industry 4.0, marked by the integration of cyber-physical systems with the Internet of Things (IoT) and services, has redefined the landscape of manufacturing and commercial sectors. This 'fourth industrial revolution' continues to reshape careers, demanding new skills from engineers who are expected to excel in advanced IDT roles. Such roles often involve managing complex digital infrastructures that support smart manufacturing processes and innovative product development, leading to lucrative and fulfilling career paths for skilled professionals.

The aim of this unit is to deepen the understanding of smart technologies and the architecture of software, systems, and departmental implementations within smart factories. It covers how advancements in computing and engineering systems are revolutionising the engineering industry, detailing their implementation, and analysing both the benefits and challenges associated with the integration of smart technologies. This unit seeks to equip students with advanced knowledge and skills to navigate and influence this dynamic field effectively.

Topics covered include: an exploration of the factors driving industrial revolutions, with a focus on Industry 4.0; an in-depth study of the technologies underpinning smart engineering and manufacturing; the control and manipulation of large data sets; the life cycles of data management; the use of programming languages to visualise the integration of smart technologies; and the creation of defensive algorithms to enhance system security and resilience against vulnerabilities.

Upon successful completion of this unit, students will have the capability to investigate and evaluate the evolution of industrial revolutions and the emerging technologies of smart engineering and manufacturing. They will learn to implement smart technologies effectively, analyse extensive data streams generated by these technologies and assess system vulnerabilities. Furthermore, students will gain practical, theoretical and technical skills necessary to develop deep-learning algorithms and maintain efficient operations of smart technologies in the workplace. They will also be equipped to mitigate risks through defensive strategies against adversarial attacks, applying their knowledge to address complex problems and enhance the efficacy of their solutions in real-world settings.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Discuss digital manufacturing systems and how they enable successful integration within a smart factory

LO2 Investigate potential applications for the integration of smart technologies within the engineering industry

LO3 Examine the principles of data science and cyber security and how the implementation of machine learning contributes to operational efficiency

LO4 Apply a deep-learning model for an industrial application.

Essential Content

LO1 **Discuss digital manufacturing systems and how they enable successful integration within a smart factory**

Building physical layer connectivity in digital manufacturing:

Automation; discrete, linear and simple tasks

The true power of the smart factory: characteristics, transparency, proactivity, optimisation, agility, advantages and connectivity.

Cyber-physical systems (CPS):

Internet of Things (IoT), sensor networks, cyber security, cloud computing and radio frequency identification

Cyber-physical production systems (CPPS): intelligence, responsiveness and connectedness

CPPS architecture: connection level, data conversion level, cyber level, cognition level and configuration level.

Design for using digital tools and devices for digital asset management:

Traditional plant automation

Modern distributed control system (DCS): capability, scalability and flexibility

Benefits of modern DCS asset management

Digital work instructions: specifications and structures.

Implementation of the digital manufacturing process:

The history of robotics and applications

Industry 4.0 robots and essential technologies and integration: smart robotics, advanced sensors, artificial intelligence, Internet of Robotic Things, cloud robotics, cognitive architecture; impact on organisations

Designing and running a smart factory.

LO2 **Investigate potential applications for the integration of smart technologies within the engineering industry**

Smart manufacturing and Industry 4.0:

Industrial revolutions and the trends leading to Industry 4.0

Advanced case studies of industrial revolution stages leading to smart manufacturing

Global trends in smart manufacturing and adoption of Industry 4.0 to meet regional needs with global vision.

Industry 4.0 technologies:

Autonomous robots: automated guided vehicles and their navigation, collaborative robots and their modes of operation, drones and their applications, autonomous robot benefits and limitations

Additive manufacturing: benefits and challenges

Internet of Things (IoT) implementation and emerging current trends.

Augmented reality (AR) and virtual reality (VR): functionality, benefits, limitations, challenges and applications

Big data analytics: data science, data mining and machine learning, benefits of data analytics

The cloud: history of the cloud, limitations and industrial applications

Simulation: digital mock-ups, CAM systems and multi-physics simulations

Technologies: horizontal and vertical systems integration.

Progression of smart manufacturing:

Manufacturing operations

Framework or manufacturing and time factors

Manufacturing iterations.

LO3 **Examine the principles of data science and cyber security and how the implementation of machine learning contributes to operational efficiency**

Data science:

Role and significance of data science in engineering and manufacturing: data versus big data, predictive modelling

Principal component analysis

Machine learning techniques: implementation for operational efficiency

Probabilities, solutions analysis and evaluation.

Data manipulation and visualisation:

Signals and noise

Sampling

Quantisation

Data manipulation

Data life cycles: creation, storage, usage, archival and destruction

End-of-life data management.

Cyber security:

Cyber security principles, design concepts

Cyber threat sources and attack strategies

Cyber security controls and intrusion detection

Business continuity and disaster recovery

Sampling.

LO4 **Apply a deep-learning model for an industrial application**

Introduction to programming software:

Introduction to Python: Pandas and other libraries, importing of Pandas and other libraries

Implementation of Python code and loading of data sets

Data visualisation.

Deep learning versus machine learning:

Analysis of use cases on deep learning and machine learning

Neural networks and AI system control implementations

Activation functions, cost functions, gradients and learning rates

Elements of reinforcement learning (RL)

Applications of deep learning to industrial scenarios.

Hacking and cyber defence models:

Impact of cyber security in manufacturing and industrial robotics

Cyber-physical systems

Examples of attacks

Resilient machine learning in secure industrial applications

Adversarial machine learning

Adversarial, exploratory, evasive and poisoning attacks

Membership inference attacks

Model extraction attacks

Ethical hacking

Resilient machine learning and defence strategies.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Discuss digital manufacturing systems and how they enable successful integration within a smart factory		**LO1 and LO2**
P1 Discuss physical layers, systems and tools for digital manufacturing processes. **P2** Explore the automation of smart factories and the use of robotics for Industry 4.0 application.	**M1** Investigate the advantages and disadvantages of digital manufacturing systems and automation in industry.	**D1** Critically evaluate the available digital and smart technologies based on industry requirements to transform a workplace from the third to fourth Industrial Revolution.
LO2 Investigate potential applications for the integration of smart technologies within the engineering industry		
P3 Determine the common enablers of industrial revolutions. **P4** Investigate the time taken to move from one industrial revolution to another with an analysis of trends to periods of transition. **P5** Evaluate the enabling technologies for each industrial revolution.	**M2** Analyse how the integration of smart technologies can transform the workplace. **M3** Justify the use of smart technologies to enable the integration of smart manufacturing.	

Pass	Merit	Distinction
LO3 Examine the principles of data science and cyber security and how the implementation of machine learning contributes to operational efficiency.		**D2** Critically analyse artificial intelligence and deep-learning techniques for intrusion detection and disaster recovery.
P6 Examine methods of data science involved with practical data analysis including ethics of data control and security. **P7** Explore data life cycles and ethical practices for each stage of data management.	**M4** Analyse cyber security principles and sources and strategies for mitigating attacks. **M5** Explore the techniques implemented for the use of machine learning within data science, manipulation and visualisation.	
LO4 Apply a deep-learning model for an industrial application		**D3** Critically evaluate the results of adversarial attacks with application of appropriate defensive strategies to a machine learning model.
P8 Apply a deep-learning model for a given industrial scenario. **P9** Analyse the difference between malicious hacking and ethical hacking.	**M6** Evaluate the results of application of a deep-learning model with recommendations.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Almada-Lobo, F. (2020) *Smart Manufacturing: Concepts and Methods*. Springer.

Ayomaya, B.A. (2022) *Digital Infrastructure for Beginners: A Beginners Guide to Understanding the World of Digital Infrastructure.* USA: Independently published.

Butun, I. (2020) *Industrial IoT: Challenges, Design Principles, Applications, and Security*. Springer.

Goodfellow, I., Bengio, Y. and Courville, A. (2020) *Deep Learning*. MIT Press.

Kim, M.J., Lee, K.H., Park, H.W. and Rhee, P.K. (2021) *Immersive Technology in Smart Manufacturing: A Practical Guide to AR and VR for Engineers*. Wiley.

Lee, J., Davari, H., Singh, J. and Pandhare, V. (2020) *Industrial AI: Applications with Sustainable Performance*. Springer.

Misra, S., Roy, C. and Mukherjee, A. (2020) *Introduction to Industrial Internet of Things and Industry 4.0*. Florida: CRC Press.

Nath, S.V. and Van Schalkwyk, P. (2021) *Building Industrial Digital Twins: Design, Develop, and Deploy Digital Twin Solutions for Real-world Industries using Azure Digital Twins*. Birmingham: Packt Publishing.

Rothman, D. (2020) *Artificial Intelligence by Example: Acquire advanced AI, Machine Learning, and Deep Learning Design Skills.* 2nd Ed. Birmingham: Packt Publishing.

Russo, R. (2020) *Data Science for Beginners: 2 Books in 1: Deep Learning for Beginners + Machine Learning with Python – A Crash Course to Go Through the Artificial Intelligence Revolution, Python and Neural Networks.* United Kingdom: Independently published.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Mahesh, B. (2020) 'Machine learning algorithms – A review', *International Journal of Science and Research*, 9(1), pp. 381–386.

Zheng, T., Ardolino, M., Bacchetti, A. and Perona, M. (2021) 'The applications of Industry 4.0 technologies in manufacturing context: A systematic literature review', *International Journal of Production Research*, 59(6), pp. 1922–1954.

Links

This unit links to the following related units:

Unit 4023: Computer-Aided Design and Manufacture (CAD/CAM)

Unit 4035: Welding Technologies

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 4099: Industrial Digitalisation Technologies for Engineers

Unit 4100: Lean Six Sigma for Engineers (leading to Green Belt)

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt)

Unit 5069: Vehicle Systems and Technology

Unit 5065: Hydrogen in Automotive Engineering

Unit Code: R/651/3081

Level: 5

Credits: 15

Introduction

The role of hydrogen in automotive engineering is becoming increasingly significant as the industry shifts towards sustainable energy solutions. With the development of alternative fuels and means of propulsion for vehicles, hydrogen is increasing in importance for the automotive sector. Hydrogen fuel cells offer a promising alternative to traditional fossil fuels, contributing to reduced emissions and enhanced energy efficiency. Globally, countries are investing in hydrogen infrastructure, with notable advancements in Europe, Asia and North America. In the UK, initiatives are emerging to support hydrogen technology integration. However, there is a skill gap in this evolving sector, necessitating expertise in hydrogen systems, safety protocols and energy management. Graduates equipped with knowledge in hydrogen automotive engineering can pursue roles such as hydrogen fuel cell engineers, automotive design specialists and sustainability consultants, to address the industry's growing demand for green technology professionals.

The aim of this unit is to introduce students to the possibilities associated with hydrogen as a fuel for vehicles and machines by providing them with an insight into current developments in the field that are allowing hydrogen to be considered a more viable alternative to fossil fuel than it has been in the past.

Among the topics that are taught in this unit are: the use of hydrogen in fuel cells; the scientific principles associated with the use of hydrogen as a fuel source; the infrastructure requirements; and how the use of hydrogen can have an impact on the global aim to achieve net zero.

On successful completion of this unit, students will be able to describe the use of hydrogen as a fuel for a range of different types of vehicle and machine. They will understand the scientific principles associated with using hydrogen for both fuel cells and as a fuel for internal combustion engines. Students will investigate the specific infrastructure requirements needed to support a reliable hydrogen fuel distribution network, making connections with the targets of achieving net zero.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Examine the use of hydrogen as a fuel type for different types of vehicle and machine

LO2 Explore the scientific principles associated with hydrogen as a fuel source

LO3 Assess the infrastructure requirements required to develop hydrogen as a viable fuel source for vehicles and machines

LO4 Analyse how hydrogen can contribute towards achieving net-zero targets.

Essential Content

LO1 **Examine the use of hydrogen as a fuel type for different types of vehicle and machine**

Fuel cell vehicles:

Types of fuel cell vehicle: cars, vans, LGVs, buses, off-road vehicles and machines

Characteristics of hydrogen as a fuel type

On-board storage of fuels

System components and layout

Electric hybrid vehicles with fuel cell range extenders

Fuel cell electric vehicle drive systems.

Polymer electrolyte membrane (PEM)fuel cell technologies:

Fuel cells: structure, materials and layout

Safe design of fuel cells

Fuels for use in fuel cells

Fuel cell systems.

LO2 **Explore the scientific principles associated with hydrogen as a fuel source**

Scientific principles:

Thermodynamics associated with hydrogen as a zero-carbon fuel for internal combustion engines

Principles of and mitigation for hydrogen embrittlement

Electrochemical reactions in fuel cells

Fuel cells and electrolysers

Emissions and emission control systems and components for hydrogen combustion engines.

Hydrogen as a fuel source:

Sources and types of hydrogen: blue hydrogen, green hydrogen, grey hydrogen

Environmental impact of the production and use of hydrogen as a fuel type

The impact of hydrogen in sustainability and environmental efficiency: influence of these factors in engineering and manufacturing decisions.

LO3 **Assess the infrastructure requirements required to develop hydrogen as a viable fuel source for vehicles and machines**

Infrastructure requirements:

Filling stations

Distribution to filling stations: tanker, pipeline, grid

On-site storage for gaseous and liquid hydrogen

On-site production of hydrogen fuel

Health and safety

Pump and dispenser standards

International standards Including ISO 14687 for hydrogen purity.

LO4 **Analyse how hydrogen can contribute towards achieving net-zero targets**

Opportunity for expansion:

Scalability of the refuelling network

Future targets for the use of hydrogen as a fuel type

Future development for automotive applications of fuel cells e.g. high temperature PEM, iridium in lieu of platinum catalyst

Adoption of hydrogen technology as an essential case of emerging and advanced technologies to improve and optimise performance in the sector.

Operational constraints:

Problems and issues with hydrogen; challenges associated with production of clean hydrogen

Water and energy consumption.

Cost implications:

Relative costs of production of different types of hydrogen

Maintenance requirements of infrastructure and vehicles.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the use of hydrogen as a fuel type for different types of vehicle and machines		
P1 Describe the types and layout of fuel cell systems used in different types of fuel cell vehicle. **P2** Explain the characteristics of hydrogen as a type of fuel for fuel cell vehicles. **P3** Examine the construction and use of fuel cells for hybrid vehicles.	**M1** Assess the design characteristics of hydrogen fuel cell vehicles.	**D1** Evaluate the use of hydrogen as a type of fuel for a range of different types of vehicle.
LO2 Explore the scientific principles associated with hydrogen as a fuel source		
P4 Explore the thermodynamic processes that take place during combustion in a hydrogen fuelled internal combustion engine. **P5** Explore the electrochemical processes that take place in fuel cells to generate electricity.	**M2** Review the environmental impact of the production of different types of hydrogen.	**D2** Evaluate the performance of hydrogen fuel cells and hydrogen internal combustion engines and their relative impact on the environment.

Pass	Merit	Distinction
LO3 Assess the infrastructure requirements required to develop hydrogen as a viable fuel source for vehicles and machines		
P6 Assess the infrastructure required to provide a reliable hydrogen fuel distribution network. **P7** Discuss the health and safety requirements for the on-site storage and dispensing of hydrogen fuels.	**M3** Assess the impact of standards on the safe provision of a hydrogen fuel distribution network.	**D3** Evaluate how existing infrastructure can be adapted and developed to provide a reliable hydrogen fuel distribution network.
LO4 Analyse how hydrogen can contribute towards achieving net-zero targets		
P8 Analyse the opportunities for scaling the hydrogen fuelling network to meet the demands of net zero. **P9** Describe the challenges associated with the large scale production of hydrogen. **P10** Investigate the cost implications of using hydrogen fuel as a means of reducing carbon emissions.	**M4** Assess the potential use of hydrogen for vehicle and non-vehicle applications as a means to achieve net-zero targets.	**D4** Evaluate the benefits and challenges associated with using hydrogen to achieve net-zero emissions targets.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Felseghi, A. (2023) *Hydrogen Fuel Cell Technology for Mobile Applications*. IGI Global.

Hacker, V. and Mitsushima, S. (2018) *Fuel Cells and Hydrogen: From Fundamentals to Applied Research.* Elsevier.

Hordeski, M. (2020) *Hydrogen & Fuel Cells: Advances in Transportation and Power*. CRC Press.

Hosseini, S. (2023) *Fundamentals of Hydrogen Production and Utilization in Fuel Cell Systems*, Elsevier.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Computer Methods in Applied Mechanics and Engineering. Available at: https://www.journals.elsevier.com/computer-methods-in-applied-mechanics-and-engineering.

Frontiers in Mechanical Engineering. Available at: https://www.frontiersin.org/journals/mechanical-engineering.

International Journal of Engineering Science. Available at: https://www.journals.elsevier.com/international-journal-of-engineering-science.

International Journal of Hydrogen Energy. Available at: https://www.journals.elsevier.com/international-journal-of-hydrogen-energy.

International Journal of Mechanical Sciences. Available at: https://www.journals.elsevier.com/international-journal-of-mechanical-sciences.

Journal of Mechanical Engineering. Available at: https://journals.sagepub.com/home/jme.

Journal of Mechanical Science and Technology. Available at: https://www.springer.com/journal/12206.

Mechanical Engineering Journal. Available at: https://www.jstage.jst.go.jp/browse/mej.

Links

This unit links to the following related units:

Unit 4013: Fundamentals of Thermodynamics and Heat Transfer

Unit 4089: Net Zero Energy Technologies I: Systems and Demand

Unit 4114: Motorcycle Engineering

Unit 5058: Automotive Structures and Materials

Unit 5062: Engine and Vehicle Design Performance

Unit 5070: Further Motorcycle Engineering

Unit 5054: Net Zero Energy Technologies II: Infrastructure and Pathways

Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt)

Unit Code: **T/651/3082**

Level: **5**

Credits: **15**

Introduction

Operational excellence has become the cornerstone of successful business and engineering management in recent times. Pioneered by visionaries such as Shigeo Shingo, Taiichi Ohno and W. Edwards Deming, they championed the four principles of continuous improvement, process optimisation, resource optimisation and productivity optimisation. These four principles help businesses and their employees achieve the highest levels of efficiency, quality and customer satisfaction.

The aim of this unit is to provide students with insight into the principles and methodologies for successful deployment of Lean Six Sigma in the context of engineering and manufacturing, and the statistical knowledge and skills to enable detailed technical analysis of continuous improvement projects. Studying this unit alongside any one of *Unit 5001 Research project* or *Unit 5002 Professional Engineering management or Unit 5041 Engineering Project* would enable a student to achieve the Black Belt award subject to submission of a project portfolio and successful completion of a multi-choice exam.

Among the topics taught in this unit are: the principles of continuous improvement; business and commercial requirements; customer requirements; processes and mapping; root cause analysis; experimentation techniques; process capability analysis; hypothesis testing; and coaching and people development methods.

On successful completion of this unit, students will be able to describe the principles and application methodology of continuous improvement using a Lean Six Sigma framework, which will enable them to lead the deployment of improvement strategies with a business. Students will be able to apply advanced statistical principles and engineering knowledge to enable identification and delivery of complex improvement projects aligned to key business goals. In addition, students will be able to understand and use coaching and people development techniques to develop and train continuous improvement practitioners.

Note: Prior to undertaking this unit it is important that students have successfully completed Unit 4100 Lean Six Sigma for Engineering and Manufacturing *(leading to Green Belt).*

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Apply technical expertise in advanced and complex Lean and Six Sigma principles and tools to enable identification and delivery of improvement opportunities aligned to key business goals.

LO2 Evaluate business, commercial and customer requirements in relation to the strategic deployment of continuous improvement in the business.

LO3 Apply advanced statistical analysis tools to determine process capability and conduct hypothesis testing.

LO4 Develop Lean Six Sigma Yellow or Green Belts through training and coaching in the principles of Lean Six Sigma thinking and Lean tools.

Essential Content

LO1 **Apply technical expertise in advanced and complex Lean and Six Sigma principles and tools to enable identification and delivery of improvement opportunities aligned to key business goals**

Lean and Six Sigma principles:

Define, Measure, Analyse, Improve, Control (DMAIC) methodology

Design for Six Sigma (DFSS) methodology and applicability

Kaizen Blitz/Kaizen Event

Definition of waste, value and non-value add activities, the 7 (or 8) wastes.

Understanding and mapping processes:

Swim lane maps

Value stream maps (VSM)

Activity network diagrams.

Determining root cause:

Differences between cause, effect and symptoms

Ishikawa diagrams

5-Whys analysis

Failure mode and effects analysis (FMEA).

Experimentation:

Full and fractional design of experiments (DOE)

Repeats, replicates, randomisation and confounding

Analysis of main effects and interaction plots

Regression and model optimisation.

LO2 **Evaluate business, commercial and customer requirements in relation to the strategic deployment of continuous improvement in the business**

Understand the business and commercial requirements:

Voice of the business (VoB) analysis

Political, Economic, Social, Technological, Environmental and Legal (PESTEL) analysis

Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis

Benefits realisation plans

Force field analysis.

Understand customer requirements:

Voice of the customer (VoC) analysis

Quality function deployment (QFD) principles

Supplier, Input, Process, Output, Customer (SIPOC) diagrams

Benchmarking analysis

Stakeholder mapping analysis

Critical to quality (CTQ) diagrams.

Strategic deployment of continuous improvement:

Generating the business case for improvement, creating the project charter (e.g. project selection, operational performance, KPIs, pitfalls, return on Six Sigma etc.)

Creating financial plans

Developing risk management plans

Preparing impact readiness reviews

Applying change management strategies

Developing the house of quality.

LO3 **Apply advanced statistical analysis tools to determine process capability and conduct hypothesis testing**

Process capability analysis:

Voice of the process (VoP) analysis

Short term versus long term data stability

Process capability metrics (C_p, C_{pk}, P_p, P_{pk})

Common and special cause variation

Principles of data normality

Transformation of non-normal data

Interpreting control charts, Shewharts 8 rules.

Hypothesis testing:

Principles of the null and alternative hypotheses

Use of truth tables, consumer risk and producer risk

Confidence intervals and the alpha risk

Application rules of typical hypothesis tests (*t*-test, *f*-test)

Use and interpretation of analysis of variance (ANOVA) tests.

LO4 **Develop Lean Six Sigma Yellow or Green Belts through training and coaching in the principles of Lean Six Sigma thinking and Lean tools**

Training and coaching methods:

Coaching versus mentoring and the differences

Typical coaching models e.g. T-GROW

Maslow's hierarchy of needs

Effective communication, listening and questioning skills, professionalism with a positive and respectful attitude

Personality types, motivational techniques and team working models (e.g. Belbin).

Lean and Six Sigma practitioner development:

Curate and deliver training material

Guide the application of appropriate improvement methods and models

Facilitate the selection of improvement projects

Guide the selection of appropriate process mapping tools.

Building a professional portfolio:

Produce relevant documentation in support of coaching, mentoring and guiding others

Create a portfolio of evidence covering the delivery of training material, coaching and mentoring sessions and guiding practitioners on lean tool selection

Elicit feedback from practitioners on training and coaching sessions, identify opportunities for personal performance improvement and create a personal development plan.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Apply technical expertise in advanced and complex Lean and Six Sigma principles and tools to enable identification and delivery of improvement opportunities aligned to key business goals		
P1 Apply continuous improvement methodologies following the steps of a recognised problem-solving methodology. **P2** Test effective uses of any two recognised methods to map and analyse processes and to identify waste.	**M1** Investigate failure modes and causes of failure using a recognised root cause analysis methodology.	**D1** Apply failure modes and effects analysis (FMEA) principles and tools to identify and manage risk in the delivery of a multi-project continuous improvement programme.
LO2 Evaluate business, commercial and customer requirements in relation to the strategic deployment of continuous improvement in the business		
P3 Evaluate business and economic risk in the context of identifying and managing continuous improvement projects. **P4** Apply methods to capture and understand the voice of the customer (VoC).	**M2** Demonstrate how voice of the business (VoB) and voice of the customer (VoC) analysis are used to build a house of quality.	**D2** Guide others in the application of voice of the business (VoB) and voice of the customer (VoC) analysis principles and tools.

Pass	Merit	Distinction
LO3 Apply advanced statistical analysis tools to determine process capability and conduct hypothesis testing		**LO3 and LO4** **D3** Guide others in the application of process capability analysis and hypothesis testing.
P5 Examine data to assess process capability for a range of engineering processes. **P6** Apply hypothesis testing principles to discriminate between multiple data sets.	**M3** Interpret complex engineering data sets for stability and normality using both process capability and hypothesis testing principles.	
LO4 Develop Lean Six Sigma Yellow or Green Belts through training and coaching in the principles of Lean Six Sigma thinking and Lean tools		
P7 Apply at least one coaching model. **P8** Develop at least one training session on the principles and/or tools of Lean Six Sigma.	**M4** Coach others in setting up and leading effective improvement teams using Lean principles.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Barsalou, M.A. (2014) *Statistics for Six Sigma Black Belts*. ASQ Quality Press.

Bicheno, J. and Holweg, M. (2016) *The Lean Toolbox 5th Edition: A Handbook for Lean Transformation*. Picsie.

Chen, C. and Roth, H. (2005) *The Big Book of Six Sigma Training Games – Creative Ways to Teach Basic DMAIC Principles and Quality Improvement Tools*. McGraw Hill.

Defoe, J. and Juran, J. (2014) *Juran's Quality Essentials: For Leaders*. McGraw Hill Education.

George, M.L. (2002) *Lean Six Sigma – Combining Six Sigma Quality with Lean Speed*. McGraw Hill.

George, M. and Rowlands, D. (2003) *What is Lean Six Sigma*? McGraw Hill Education.

Jonsson, M. (2022) *The Complete Corporate Coaching Toolkit: The Quintessential Guide for 21st Century Business Coaches and Leaders*. Independently published.

Kubiak, T.M. and Benbow, D.W. (2017) *The Certified Six Sigma Black Belt Handbook*. 3rd Ed. Independently published.

Pande, P., Neuman, R. and Cavanaugh, R. (2014) *Six Sigma Way: How to Maximize the Impact of Your Change and Improvement Efforts*. 2nd Ed. McGraw Hill Education.

Peters, W. (2023) *Lean Six Sigma: Beginner's Guide to Improving Quality, Speed, and Efficiency With the Six Sigma Methodology*. Independently published.

Pyzdek, T. and Keller, P. (2023) *The Six Sigma Handbook, Sixth Edition: A Complete Guide for Green Belts, Black Belts, and Managers at All Levels*. McGraw Hill.

Rother, M. and Shook, J. (2003) *Learning to See – Value Stream Mapping to Create Value and Eliminate MUDA – A Lean Tool Kit Method and Workbook*. The Lean Enterprise Institute.

Smalley, A. (2004) *Creating Level Pull – A Lean Production System Improvement Guide for Production Control, Operations and Engineering Professionals*. The Lean Enterprise Institute.

Soltero, C. and Boutier, P. (2012) *The 7 Kata – Toyota Kata, TWI and Lean Training*.

Tague, N. (2023) *The Quality Toolbox*. ASQ Quality Press.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Anthony, J. (Editor) *International Journal of Lean Six Sigma*. Emerald Publishing.

Damodaran, P. (Editor) *International Journal of Six Sigma and Competitive Advantage*. Inderscience Publishers.

Links

This unit links to the following related units:

Unit 4004: Managing a Professional Engineering Project

Unit 4100: Lean Six Sigma for Engineering and Manufacturing (leading to Green Belt)

Unit 4017: Quality and Process Improvement

Unit 4075: Business Improvement Techniques for Engineers

Unit 4077: Lean Techniques for Manufacturing Operations

Unit 5001: Research Project

Unit 5002: Engineering Project Management

Unit 5041: Engineering Project

Unit 5067: Vehicle Operations

Unit Code: Y/651/3083

Level: 5

Credits: 15

Introduction

The transportation industry is experiencing a significant transformation worldwide, transitioning from traditional vehicle ownership to app-based shared mobility services. This shift is fuelled by the increasing popularity of vehicle sharing platforms and the rise of hybrid, electric and autonomous vehicles. Additional factors such as increased traffic, transportation costs and environmental concerns also need to be considered. As the sector evolves, there is a pressing need for professionals to be adept in modern vehicle operations and maintenance strategies to take on dynamic roles and emerging career opportunities, with the skills required to excel in both conventional and innovative automotive environments. Local and global sustainability goals add another important dimension in developing the current and future automotive workforce to meet the needs of the sector.

The aim of this unit is to equip students with a thorough understanding of various vehicle maintenance frameworks, relevant terminology, legal aspects and core organisational competencies. Through engaging with case studies from enterprises of varying sizes, students will learn to apply both qualitative and quantitative tools, gaining insights into effective operations and maintenance strategies across a spectrum of conventional and modern vehicles.

Students will explore a comprehensive range of topics essential to vehicle operations and maintenance. These include the overall vehicle operations environment, diverse maintenance strategies to optimise business performance, and the examination of different maintenance contracts. The curriculum also covers safe vehicle management practices, the economic and legal obligations of vehicle operations, and the strategic business acumen necessary for the effective management of an enterprise's vehicle operations. Additionally, students will learn to utilise resources effectively, monitor and evaluate vehicle fleet management systems in accordance with legal and governmental standards, and implement necessary risk mitigation measures.

On successful completion of this unit, students will be capable of designing and implementing a vehicle operations and maintenance strategy for an automotive enterprise that adheres to legal and governmental norms. They will be able to evaluate the effectiveness of different solutions for organisations seeking to modernise their current practices. Through case studies, students will assess operational excellence and propose risk mitigation strategies to comply with local norms, thus showcasing their readiness to have a significant impact on the mobility services industry.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Explore vehicle operations in both conventional and modern settings as part of developing and implementing a strategic plan for an enterprise

LO2 Examine how conventional and modern planning, systems and methods are utilised to manage vehicle operations and maintenance of a vehicle fleet to make improvements

LO3 Analyse strategic and operational level changes required to manage operations and maintenance activities of electric and autonomous vehicles to meet local needs

LO4 Evaluate a risk management plan for a conventional or modern vehicle fleet to address legal and operations implications.

Essential Content

LO1 **Explore vehicle operations in both conventional and modern settings as part of developing and implementing a strategic plan for an enterprise**

Vehicle operations strategy and terminology:

Need for creation of vision of the automotive enterprise

Core competencies, new technologies, terminology

Vehicle operations overview: manufacturing perspective

Vehicle operations: maintenance perspective.

Internal and environmental audit:

Qualitative and quantitative tools

SWOT analysis, Porter's five force analysis for automotive industry

McKinsey 7S framework

Political, Economic, Socio-cultural, Technological, Legal, Ecological (PESTLE).

Planning process:

Small, medium, large enterprises

Corporate planning process: conventional and modern enterprises, setting up measurable goals

Operational planning and workflows

Case studies: vehicle enterprises in the region, example strategic plans.

LO2 **Examine how conventional and modern planning, systems and methods are utilised to manage vehicle operations and maintenance of a vehicle fleet to make improvements**

Types of vehicle maintenance contracts:

Contract hire

Lease hire

Rental

Manufacturer contract.

Vehicle maintenance contracts:

Legal aspects of conventional versus modern contracts

Controls, staffing

Records, financial considerations

Company taxation

Operational factors, operator licencing.

Fleet maintenance management systems:

Conventional versus modern

Selection criteria

Management systems

Customer requirements.

LO3 **Analyse strategic and operational level changes required to manage operations and maintenance activities of electric and autonomous vehicles to meet local needs**

Fleet maintenance control systems:

Computerised operation

Computer-based systems

Software and hardware planning

Vehicle inspection reporting.

Vehicle maintenance servicing schedules:

Vehicle and battery diagnostics

Vehicle prognostics

Vehicle records through Internet of Things and cloud services

Digital twins for servicing.

Response to trends and advancements:

Digitalisation, digitisation, digital servitisation

Impact on strategic and operational level changes; use of technologies to optimise performance

Industry case studies on electric and autonomous vehicles.

LO4 **Evaluate a risk management plan for a conventional or modern vehicle fleet to address legal and operations implications**

Legal and operational implications:

Contract law (sale of goods and supply of goods and services)

Transport Act

Vehicle registration and testing

Environmental legislation.

Legal and insurance requirements:

Operator's licence

Regulatory roadworthiness test (e.g. MoT in UK and Contrôle Technique in France), or equivalent, to meet regional requirements

Sustainability and environmental considerations and impact in decision-making.

Implications and penalties, risks and training:

Risk assessment and responsibilities: risk assessment process, procedures and documentation used in vehicle fleet

Statutory and organisation health and safety policies, procedures and regulations that must be adhered to

Staff qualifications; facilities

Defect reporting and rectification

Environmental requirements for end-of-life strategy and waste disposal

Staff training, licences.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore vehicle operations in both conventional and modern settings as part of developing and implementing a strategic plan for an enterprise		**LO1 and LO2**
P1 Explore core competencies needed to carry out vehicle operations in a modern setting. **P2** Produce vehicle operations workflow from a maintenance perspective.	**M1** Analyse an operations strategy based on qualitative and quantitative tools for a modern and conventional enterprise.	**D1** Develop a vehicle operations strategy for a given enterprise using conventional and modern settings: set vision, measurable targets and maintenance management.
LO2 Examine how conventional and modern planning, systems and methods are utilised to manage vehicle operations and maintenance of a vehicle fleet to make improvements		
P3 Examine legal aspects of a maintenance contract and its operational factors. **P4** Discuss the financial, taxation and licencing aspects of vehicle operations.	**M2** Analyse a vehicle fleet maintenance management system based on customer requirements.	

Pass	Merit	Distinction
LO3 Analyse strategic and operational level changes required to manage operations and maintenance activities of electric and autonomous vehicles to meet local needs		**LO3 and LO4**
P5 Recommend software and hardware selection for modern vehicle maintenance. **P6** Analyse the use of IoT for modern vehicle operations and maintenance.	**M3** Evaluate strategic and operational changes needed to upgrade existing infrastructure for electrical and autonomous vehicle maintenance.	**D2** Given a vehicle portfolio consisting of a mix of conventional and electric and autonomous vehicles of a client, evaluate a vehicle operations and maintenance strategy along with a proposal for a risk mitigation plan to meet local needs and sustainable life cycle aspects.
LO4 Evaluate a risk management plan for a conventional or modern vehicle fleet to address legal and operations implications		
P7 Produce a risk management plan to comply with local environmental legislation for vehicle operations. **P8** Evaluate the effectiveness and application of a regulatory roadworthiness test or equivalent testing for a modern vehicle fleet.	**M4** Prepare a risk assessment and mitigation strategy for a given vehicle fleet based on analysis of legal and operational implications.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Carter, P., Price, D. and Emmett, S. (2004) *Stores and Distribution Management*. 4th Ed. Liverpool: Liverpool Academic Press.

Dolce, J.E. (2009) *Analytical Fleet Maintenance Management*. 3rd Ed. Warrendale, PA: SAE International.

Gonçalves, P., de Castro, G., Santiago, E.S. and de Araújo, F.P. (2023) *Heavy Vehicle Fleet Management and Maintenance*. Our Knowledge Publishing, SAE International.

Hibbs, J. (1999) *An Introduction to Transport Studies*. 2nd Ed. London: Kogan Page.

Levitt, J. (2009) *Handbook of Maintenance Management*. New York: Industrial Press Inc.

Lowe, D. (2000) *Management of Dangerous Goods Safety Manual*. 2nd Ed. London: Kogan Page.

Lowe, D. (2006) *Pocket Guide to LGV Drivers' Hours and Tachograph Law*. 3rd Ed. London: Kogan Page.

NAFA (2023) *Automotive Fleet Guidebook*. 2023 Ed. Available at: https://www.nafa.org.

Rushton, A., Croucher, P. and Baker, P. (2006) *The Handbook of Logistics and Distribution Management*. 3rd Ed. London: Kogan Page.

Tom, D. and Pells, H. (2024) *Electric and Hybrid Vehicles*. 3rd Ed. Kindle Edition.

Wilson, D. (2024) *The Ultimate Guide to Commercial Vehicle Fleet Management: How to reduce the cost of running your fleet*. Kindle Edition.

(2024) *Automotive Fleet Guidebook*. 3rd Ed. Routledge.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Commercial Motor. Reed Business Information.
Available at: https://www.commercialmotor.com/.

Distribution Business. UK Transport Press.
Available at: https://www.distributionbusiness.co.uk/.

Distribution. DMG. Available at: https://www.distribution-dmg.com/.

Motor Transport. Reed Business Information.
Available at: https://www.motortransport.co.uk/.

Transportation Research Record: Journal of the Transportation Research Board. Sage Publications Inc. Available at: https://journals.sagepub.com/home/trr.

Transport Reviews. Taylor & Francis. Available at:
https://www.tandfonline.com/journals/ttrv20.

Links

This unit links to the following related units:

Unit 4012: Engineering Management

Unit 4017: Quality and Process Improvement

Unit 4100: Lean Sigma for Engineers (leading to Green Belt)

Unit 5063: Advanced Hybrid and Electric Vehicle Technologies

Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt)

Unit 5068: Vehicle Parts Management

Unit Code:	**A/651/3084**
Level:	**5**
Credits:	**15**

Introduction

The automotive industry has attained a global stature during the last half-century as several international brands started their manufacturing and sales collaboratively across regions. The vehicle parts industry is a vibrant part of the automotive industry and has embraced several technological developments in information technology and e-commerce. The collaborative nature of automotive supply chains has also changed the dynamics of vehicle parts management and opened up exciting career opportunities around the world. Stringent quality control and sustainability goals have transformed the vehicle parts supply industry. The impact of the chip shortage on the automotive industry underscores the need for the timely supply of parts to meet automotive industry demand. The demand for highly skilled and creative human resources that can use multimedia, augmented and virtual-reality tools, and e-commerce platforms is evident in the vehicle parts distribution industry.

The aim of this unit is to enable students to understand the role and importance of vehicle parts management in the globalised automotive supply chains. Students will learn about key aspects of vehicle parts management to prepare for careers in this sector.

Among the topics taught in this unit are: management of vehicle parts distribution and supply in the automotive industry; roles and responsibilities of parts suppliers, parts managers and franchise suppliers; managing customers; stock management systems and the different types of stock control systems; the function and layout of a parts department, warehouse management and automation, ergonomics and safe working practices, and potential risks.

On successful completion of this unit, students will be able to evaluate efficient after-sales service through vehicle parts management systems with the help of modern tools such as information technology platforms, automated warehouses and distribution systems. Students can prepare parts catalogues and carry out profitability analysis, as well as analyse supply chain challenges, constraints and legal considerations relating to international trade, and environmental, ethical, and political issues relating to parts supply.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Explore a global framework for vehicle parts supply and management for efficient after-sales service

LO2 Explain stock management systems for reducing part inventory and improving traceability of parts

LO3 Analyse the functions and processes in a vehicle parts supplier operation

LO4 Evaluate global vehicle parts supply chain and customer relationship campaigns.

Essential Content

LO1 **Explore a global framework for vehicle parts supply and management for efficient after-sales service**

Parts suppliers:

Global manufacturer network (e.g. vehicle, component manufacturer)

Distributor (e.g. dealerships)

Wholesaler

National and international retail chains, DIY outlets

High street retailers

Case studies of legal aspects and contracts of UK, EU and rest of the world.

Customers:

Vehicle sales, car fleet, van fleet, commercial fleet

Body repairer

Garage, service station

Breakdown and recovery, repair, after market

National and international customers.

Responsibilities:

Financial (e.g. turnover, profitability)

Development of customer base and new international markets

After-sales services, approaches

Management of staff and department

National and international franchise supplier: agreements, franchise management

Stakeholder engagement and teamwork: create and maintain positive, professional, trusting and ethical working relationships with the team and the wider range of internal, external and connected stakeholders.

Framework development and documentation skills:

Parts flow analysis, documentation used such as job cards or build records, 2D and 3D drawings or models, bill of materials (BOM), cost analysis reports, compliance report, standard operating instructions (SOIs), standard process instructions (POIs), engineering query notifications (EQNs) and drawing query notifications (DQNs)

Use financial planning, recording and review processes and documentation such as departmental budgets, estimating, cost control, cost forecasting and investment appraisal.

LO2 **Explain stock management systems for reducing part inventory and improving traceability of parts**

Efficiency of stock management systems:

Maintenance of stock

Warranty

Financial control

Economic order quantity (EOQ)

Physical stock control.

Stock control and part traceability:

Card systems

Electronic ordering and cataloguing

Just-in-time (JIT)

Auto-ID technologies and part traceability

Integration with enterprise resource planning software with e-commerce capabilities.

Computerised documentation recording systems:

Maintenance of stock levels, reporting and managing shortages (e.g. chip shortages)

Automatic order generation

Stock and sales analysis (i.e. lost sales, demand level fluctuations, parts quality and satisfaction, dashboard data, use of mathematical/statistical techniques).

LO3 **Analyse the functions and processes in a vehicle parts supplier operation**

Storage and warehouse management:

Goods flow and parts storage

Sales displays

Delivery and distribution methods

Warehouse automation, scoping and ergonomics

Benchmarking against competitors and sharing safe practices.

Documentation:

Order processing, data handling and financial considerations

Produce and present product and process documentation by collecting, analysing and summarising information and trends: bill of materials, delivery note and invoice, stock audit report and warranty report, standard operating instructions, build manuals

Damage reporting and management risk assessment; potential implications on safety, quality and delivery

Apply documentation control processes and procedures such as format, location, access and authorisation.

LO4 **Evaluate global vehicle parts supply chain and customer relationship campaigns**

External factors of global vehicle parts supply chain:

Legal and ethical aspects

Environmental aspects of vehicle parts distribution across the world with reference to circular economy

Career opportunities in global vehicle parts supply chain.

Promotion campaigns in a vehicle parts operation:

Types of campaigns, suitability and selection

Technical festivals, trade events

Webinars and podcasts

Virtual reality, mobile phone apps

Chatbots and AI copilots for customer service

Career opportunities in information technology aspects of global vehicle parts supply chain.

In-house factors:

Staff training and CPD: developing campaigns and promotional strategies, how to benchmark against local themes and competitors

Customer relationship management

Quality of service and customer feedback analysis, closing feedback loops

Career opportunities in customer relationship of global vehicle parts supply chain.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore a global framework for vehicle parts supply and management for efficient after-sales service		**LO1 and LO2**
P1 Explore key elements of global vehicle part supply chain and associated emerging opportunities. **P2** Explain the different methods of dealing with national and international customers and franchise agreements.	**M1** Prepare part flow and documentation such as BOM, SOI, EQN, DQN. **M2** Investigate the responsibilities of the parts manager and obligations and responsibilities of the franchise supplier.	**D1** Present just-in-time (JIT) part inventory and use of auto-ID technologies in a vehicle part supply management system to improve quality of after-sales service.
LO2 Explain stock management systems for reducing part inventory and improving traceability of parts		
P3 Explain selection stock management systems for a given scenario. **P4** Compare various strategies for improving traceability of parts.	**M3** Analyse lost sales, with a forecast of new demand to deliver a spreadsheet-based tool.	

Pass	Merit	Distinction
LO3 Analyse the functions and processes in a vehicle parts supplier operation		**LO3 and LO4**
P5 Analyse the effectiveness of a chart of warehouse automation that you have produced for smooth parts storage and distribution. **P6** Document processes in a vehicle parts operation using a stock audit report and warranty analysis.	**M4** Propose scope for automation of functions and processes in parts distribution with a risk assessment for the parts department.	**D2** Critically evaluate various sustainable life cycle aspects of global vehicle part supply chain based on local themes, including benchmarking the functions and processes with competitors.
LO4 Evaluate global vehicle parts supply chain and customer relationship campaigns		
P7 Prepare a document on legal, ethical and environmental aspects of global vehicle parts distribution. **P8** Evaluate emerging information technology opportunities for attracting new customers.	**M5** Carry out a survey to collect customer feedback and close the feedback loops using customer relationship management tools that can improve quality of after-sales service.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

AIAG (2018) *CQI-28: AIAG Traceability Guideline (Hardcopy with Downloadable Assessment)*.

AIAG (2022) *CQI-14 Automotive Warranty Management: A Guideline for Industry Best Practices*. 4th Ed.

Halderman, J.H. and Ward, C. (2023) *Automotive Technology: Principles, Diagnosis, and Service*. 7th Ed. Pearson.

Hillier, V. and Coombes, P. (2011) *Hillier's Fundamentals of Motor Vehicle Technology*. 6th Ed. Nelson Thornes.

Stoakes, G. (2011) *Level 1 Principles of Light Vehicle Operations Candidate Handbook (Motor Vehicle Technologies)*.

Tersine, R.J. (1993) *Principles of Inventory and Materials Management*. 4th Ed. Pearson.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Automotive Logistics. Available at: https://www.automotivelogistics.media/.

International Journal of Automotive Technology and Management. Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijatm.

International Journal of Production Economics. Available at: https://www.journals.elsevier.com/international-journal-of-production-economics.

Journal of Operations Management. Available at: https://www.journals.elsevier.com/journal-of-operations-management.

Motor Industry Magazine. Available at: https://www.motorindustrymagazine.com/.

Supply Chain Management: An International Journal. Available at: https://www.emerald.com/insight/publication/issn/1359-8546.

Links

This unit links to the following related units:

Unit 4012: Engineering Management

Unit 4017: Quality and Process Improvement

Unit 4100: Lean Sigma for Engineers (leading to Green Belt)

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 5066: Lean Six Sigma for Engineers (leading to Black Belt)

Unit 5069: Vehicle Systems and Technology

Unit Code: **D/651/3085**

Level: **5**

Credits: **15**

Introduction

Modern-day vehicles are equipped with a plethora of electronic aids and enhancements, where the convergence of electronics and automotive engineering unlocks a world of innovation and performance. Wider understanding of vehicle systems and technologies combined with intricate knowledge of electronic systems that power modern vehicles, from advanced driver assistance systems to passenger safety features and beyond, is essential for carrying out diagnosis and repair of automotive systems.

The aim of this unit is to enable a student to delve into the fascinating realm of vehicle electronics, covering a wide array of systems and technologies that enhance vehicle performance, safety, comfort and convenience. From anti-lock braking systems (ABS) and traction control, to power steering, active suspension, stability control and vehicle security, students will gain insight into the inner workings of these critical systems and their integration within modern vehicles using a combination of theoretical knowledge and practical hands-on exercises.

Topics covered include: diagnosis and repair of electronic systems; diagnostic trouble codes; system malfunctions; replacement of faulty components; identification and rectification of a range of issues in vehicle electronic systems; and emerging technologies and trends in vehicle electronics including advanced driver assistance systems (ADAS), passenger protective systems and HVAC systems.

On successful completion of this unit, students will have acquired a comprehensive understanding of vehicle systems and technology, which are practical skills necessary to diagnose and repair electronic systems in modern vehicles with a forward-thinking perspective on the future of automotive technology.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Examine a variety of electronic systems found in vehicles

LO2 Solve issues in vehicle electronic systems by replacing faulty components to restore system functionality

LO3 Apply advanced diagnostic techniques to identify and address complex issues in vehicle electronic systems

LO4 Review emerging technologies and trends in vehicle electronics and connectivity features.

Essential Content

LO1 **Examine a variety of electronic systems found in vehicles**

Vehicle dynamics and handling systems:

Advanced power steering: components of integral power steering with electronic control; principles of operation; electrical and hydraulic circuit diagrams; control systems; system operation under various conditions e.g. parking, negotiating bends

Active suspension and ride control: components of active vehicle chassis management system including self-levelling suspension, ride control, electronic damper control and active rear suspension/axle control; electrical and hydraulic circuit diagrams; system operation under various conditions e.g. cruise, acceleration, braking, cornering

Anti-lock braking (ABS): principles of operation and components of an anti-lock braking system e.g. electrical and hydraulic circuits, system operation under various conditions such as emergency braking, ice

Traction control: anti-slip regulations (ASR); principles of operation and components of a traction control system e.g. electrical and hydraulic circuits; system operation during acceleration, cornering and braking.

Passenger comfort:

Central locking, keyless entry and security: components of microprocessor-controlled central locking and thief proofing system; operating principles including infrared control, Doppler movement sensing, crash sensing, failsafe and safety features; system operation under various conditions e.g. attempted break-in, accident; developments in vehicle security systems

Environmental control: components of integral heating, ventilation and air conditioning (HVAC) system; operating principles; sensing and control functions; system operation under various conditions; developments in vehicle environmental control systems

Passenger protection: components of air-bag systems e.g. front and side impact systems; operating principles; operation of system during frontal and side impact; passenger restraints e.g. seat belt tensioners and head restraint; developments in driver and passenger impact protection.

LO2 **Solve issues in vehicle electronic systems by replacing faulty components to restore system functionality**

Service and repair procedures:

Manufacturers' recommendations for service and repair

Safety aspects, service procedures (e.g. high-voltage propulsion system vehicles)

Specialist equipment and tools required

Correct test conditions

Inter-relationships of systems.

Identification of faults:

Manufacturer checking procedures

Sensor and actuator data sheets

Diagnostic trouble codes

Appropriate fault-finding techniques including failure modes and mean analysis and systemic fault diagnosis

Control unit interrogation

Fault diagnostic tests: testing e.g. visual inspection, functional tests and system condition monitoring systems

The use of oscilloscopes, multimeters, and power probes to effectively diagnose electrical/electronic malfunctions and incorrect signals.

Rectification of faults:

Appropriate fault location and justification of repair

After-repair diagnostics, evaluating repair and ensuring system responsiveness

Application of fault diagnosis techniques, appropriate justifications of repair, quality control of repair and final sign-off of completed work

Repair procedure and diagnosis justifications, presentation of results and tests.

LO3 **Apply advanced diagnostic techniques to identify and address complex issues in vehicle electronic systems**

Diagnostic techniques:

Deep interrogation of systems, to include live and recorded data

Bench testing of components

Analysis of calibration maps

Sensor and actuator operating parameters

CAN/ISO BUS signals and messaging sequences

Binary and hexadecimal signals and communication

Evaluation of communication languages and faulty signals.

System calibration and repair:

Recalibration of software

Produce and upload calibration files

Produce CAN communication data, identifying hierarchical messaging and signals

Updates, factory resets and reprogramming

Presenting technical data and justifications of repair.

LO4 **Review emerging technologies and trends in vehicle electronics and connectivity features**

Driver assistance:

Functional safety standard ISO26262 and safety of the intended function ISO 21448

Integrated dynamic stability control: functional description of system to include operational criteria e.g. understeer, lateral acceleration, vehicle rotation speed, steering angle and wheel speeds

Lane keep assist and control of vehicle, functional description of system to include operational criteria, sensors and monitoring devices

Dynamic cruise control: functional description of system to include operational criteria, sensors and monitoring devices

Autonomous emergency braking (AEB)

Corrective strategies of systems e.g. braking control and engine power regulation

Sensing components and electrical/hydraulic circuits

Trends in advanced driver assisted systems (ADAS).

Autonomous driving and connected vehicles:

SAE J3016: levels of driving automation

Autonomous driving: functional description of system to include operational criteria, sensors and monitoring devices; GPS systems, cameras and control of driving systems

Radar versus LiDAR versus camera systems

Autonomous parking: functional description of system to include operational criteria, sensors and monitoring devices

Connected vehicles: GPS, internet, connectivity with other vehicles Development of an autonomous vehicle infrastructure for the future and how vehicles will communicate and interact

Cybersecurity and automotive security protocols (ISO21434)

Ethical issues surrounding autonomous vehicles.

Promote the use of emerging and advanced technologies:

Strategic direction, role of management, role of employees, technology ambassadors, use cases and application, performance gains and efficiencies, wider impact.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine a variety of electronic systems found in vehicles		**LO1 and LO2**
P1 Explain the principles of operation and major components of electronic systems. **P2** Examine the operation of a passenger protection system including identification of normal operating parameters.	**M1** Explain the operation of various electronic systems under a variety of road, environmental and operating conditions.	**D1** Present analysis of faults, interpretation of data and rectification results from a fault diagnosis test to technical audiences.
LO2 Solve issues in vehicle electronic systems by replacing faulty components to restore system functionality		
P3 Explain service and repair procedures for advanced electronic systems. **P4** Solve faults by carrying out fault diagnosis tests on advanced electronic systems.	**M2** Repair electronic systems, including post-repair testing to ensure safe operation.	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Apply advanced diagnostic techniques to identify and address complex issues in vehicle electronic systems</td><td rowspan="4">LO3 and LO4

D2 Produce a technical report including calibration files, signals and communication language of a conceptual autonomous vehicle installed with all driving assistance aids.</td></tr>
<tr><td>P5 Interpret correct communication signals within a CAN/ISO bus system.

P6 Apply correct calibrations and maps within electronic systems.</td><td>M3 Rectify software calibration issues within an electronic system.</td></tr>
<tr><td colspan="2">LO4 Review emerging technologies and trends in vehicle electronics and connectivity features</td></tr>
<tr><td>P7 Review the principles of operation and major components of advanced driver assistance systems.

P8 Explain the principles of operation, including identification of major components, of autonomous driving systems.</td><td>M4 Explain the operation of various driver assistance, automated and autonomous systems under a variety of road, environmental and operating conditions.</td></tr>
</table>

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Badawy, W. and Jullie, G.A. (Eds.) (2021) *Automotive Cybersecurity: Engineering Challenges for Connected and Automated Vehicles.* Cham: Springer.

Beiker, S. (2021) *Automotive Technology: Principles, Diagnosis, and Service.* 6th Ed. Upper Saddle River, NJ: Pearson.

Chen, T.D. (2022) *Automotive Electronics Reliability: Driving New Technology in Electrified and Autonomous Vehicles.* Hoboken, NJ: Wiley.

Denton, T. (2020) *Automated Driving and Driver Assistance Systems.* Oxon: Routledge.

Dimitrakopoulos, G., Tsakanikas, A. and Panagiotopoulos, E. (2021) *Autonomous Vehicles Technologies, Regulations, and Societal Impacts.* London: Elsevier.

Li, Y. and Shi, H. (2022) *Advanced Driver Assistance Systems and Autonomous Vehicles from Fundamentals to Applications.* New York: Springer.

Winner, H., Wachenfeld, W. and Lutz B. (2022) *Autonomous Driving: Technical, Legal and Social Aspects.* 2nd Ed. Berlin: Springer.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

Khan, F., Kumar, R.L., Kadry, S., Maytham N.M. and Nam, Y. (2021) 'Autonomous vehicles: A study of implementation and security', *International Journal of Electrical and Computer Engineering*, 11, pp. 3013–3021. 10.11591/ijece.v11i4.

Othman, K. (2022) 'Exploring the implications of autonomous vehicles: A comprehensive review', *Innovative Infrastructure Solutions*, 7(2), pp. 1–32.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 5063: Further Hybrid and Electric Vehicle Technologies

Unit 5070: Further Motorcycle Engineering

Unit Code: **F/651/3086**

Level: **5**

Credits: **15**

Introduction

Engineers employed within the motorcycle industry are required to have a wide-ranging knowledge of the various types of motorcycles being produced. A deeper understanding of the physical principles involved in motorcycle operation is necessary to operate in a safe and efficient way. With the increasing demand for innovative and sustainable motorcycle designs, future job roles in the industry will expand to include positions such as electric motorcycle engineers, advanced materials specialists and autonomous vehicle designers. The motorcycle industry's growth necessitates a continual influx of skilled professionals who are adept at leveraging cutting-edge technologies and addressing the evolving needs of the market.

This unit builds on the preliminary knowledge and skills introduced in *Unit 4114: Motorcycle Engineering*. It will provide students with a more comprehensive knowledge of engineered systems and theories of motorcycle design and operation including adaptations for volume production and rider ergonomics.

Topics included in this unit are: determining the forces on a motorcycle at low and high speeds; the relationship between design and geometry and function; the comparison of types of motive power; 2-stroke, 4-stroke, single and multiple cylinders and battery power; systems needed for control and compliance with regulations; ABS rider assistance; and fuel mapping and emissions.

On successful completion of this unit, students will have a comprehensive knowledge of motorcycles, to determine the motorcycle's function and performance criteria giving them knowledge and analytical skills to behave efficiently and safely.

Learning Outcomes

By the end of this unit a student will be able to:

LO1 Analyse the dynamic forces encountered by a motorcycle in normal use

LO2 Assess the design geometry and considerations for a variety of motorcycles

LO3 Evaluate the motive power of a motorcycle

LO4 Analyse the main aspects of motorcycle systems.

Essential Content

LO1 **Analyse the dynamic forces encountered by a motorcycle**

Longitudinal forces:

Effect of acceleration

Effect of braking: brake use when subject to differing surface and lean angles (e.g. entering and leaving corners).

Cornering forces:

Low speed: gyroscopic balance

High speed: effect of counter steering

Determination of lean angle (effect of angular acceleration).

Environmental effects:

Stability in headwinds, crosswinds and tailwinds

Aerodynamics: use of fairings and bodywork

Rider comfort, elimination of wind noise and buffeting protection of componentry.

LO2 **Assess the design geometry and considerations for a variety of motorcycles**

Frame geometry: effects of change:

Intended function: distance riding, off-road/dual sport, efficiencies, high performance

Steering geometry: effect of altering rake angle, offset, normal and mechanical trail

Chassis and frames, power trains (engine/gearbox) as a structural element of design

Alternative materials for structure: steel, aluminium, composites.

Rider ergonomics:

Size-range adaptations

Rider comfort: design considerations, new clothing materials, climatic conditions

Performance

Wind resistance.

Intended usage adaptations:

Competition (road racing, motocross, trials)

Commuter motorcycles

Service motorcycles: armed forces, police, paramedic.

LO3 **Evaluate the motive power of a motorcycle**

Internal combustion (IC) engine configuration

Multiple cylinder layout, parallel Twins, 'V' twins, horizontally opposed twins, triple cylinders and 4 cylinders

Variations in horsepower and torque.

Ignition systems:

Electronic fuel injection, electronic ignition, engine management units

Electromechanical: carburettors, contact ignition systems.

Alternative power sources:

Electrical/battery power

Hydrogen

Ethanol-based fuels

Variations in horse power and torque

Future legislative requirements.

LO4 **Analyse the main aspects of motorcycle systems**

Rolling chassis:

Brakes, twin discs, single discs, drum brakes

Calculation of braking torque, pressure at caliper and master cylinder

Wheels and tyres: application, competition road racing, motocross, off-road, smart tyres

Advanced suspension: adjustment systems preload, rebound, compression, electronically adjustable suspension, integrated chassis electronics and stability control

Modular frame design: swappable frame components for customisation and upgrades of various parts of the chassis

Legal framework, regulation, policies, professional standards, compliance

Case studies: latest research and advancements in motorcycle systems.

Motorcycle electronic system:

Fuelling and emissions' legislation: Euro 5 and Euro 6

Rider assistance: advanced braking system (ABS), engine mapping modes, anti-wheelspin

GPS systems applicable to motorcycles

Future technical developments: radar lidar assist, adaptive cruise control, collision avoidance, lane assist.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse the dynamic forces encountered by a motorcycle in normal use		**LO1 and LO2**
P1 Determine a variety of lean angles observed due to variations in velocity and radius of bend. **P2** Analyse the effect of counter steering in controlling a motorcycle.	**M1** Analyse the effect that differing surfaces may have on cornering efficiency.	**D1** Critically analyse the design of a high-performance racing motorcycle with respect to high-speed cornering.
LO2 Assess the design geometry and considerations for a variety of motorcycles		
P3 Assess the development of frame design including variation of materials. **P4** Evaluate the variation in ergonomic needs for motorcyclists and the environment.	**M2** Investigate the design variations in motorcycles considering their intended use and efficiencies.	

Pass	Merit	Distinction
LO3 Evaluate the motive power of a motorcycle		**LO3 and LO4**
P5 Create an academic poster to explore the variations in engine configuration and power/torque. **P6** Evaluate future developments in motorcycle power systems.	**M3** Evaluate the effect that alternative fuels may have on motorcycle performance.	**D2** Critically evaluate the effects that future developments in motorcycle legislation may have on design.
LO4 Analyse the main aspects of motorcycle systems		
P7 Analyse the trends in braking and suspension design, and the key electronic aspects of a motorcycle system. **P8** Investigate future legislative requirements on motorcycle design.	**M4** Evaluate the impact that future legislation may have on motorcycle performance.	

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Briora, G. A. (2022) *Motorcycle Geometry and Suspension Adjustment.* GA Academy.

Foale, T. (2006) *Motorcycle Handling and Chassis Design: The Art and Science*. Tony Foale Designs.

Inman, G. and Adi, G. (2020) *How to Build a Motorcycle: A Nut-and-Bolt Guide to Customizing Your Bike.* Orion Publishing Co.

Livesey, A. (2021) *Motorcycle Engineering*. London and New York: Routledge.

Lot, R. and Sadauckas, J. (2021) *Motorcycle Design Vehicle Dynamics Concepts and Applications*. Lulu Press.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

International Journal of Motorcycle Studies. Available at: https://motorcyclestudies.org/.

International Journal of Vehicle Design. Inderscience Publishers. Available at: https://www.inderscience.com/jhome.php?jcode=ijvd.

Journal of Mechanical Engineering. Available at: https://journals.sagepub.com/home/jme.

Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. Available at: https://journals.sagepub.com/home/pia.

SAE International Journal of Transportation Safety. Available at: https://www.sae.org/publications/journals/content/10.4271/10-02-01-0001.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4092: Vehicle Dynamics and Performance

Unit 4114: Motorcycle Engineering

Unit 5058: Automotive Structures and Materials

Unit 5071: Heavy Vehicles II

Unit Code H/651/3087

Level: 5

Credits: 15

Introduction

The heavy vehicle industry is experiencing significant advancements across several key systems, enhancing the functionality and environmental compliance of both passenger and goods vehicles. Innovations in braking systems are improving safety and responsiveness, while developments in suspension systems ensure better load distribution and stability for varied weights. Transmission technologies are evolving to increase efficiency and reduce urban emissions. Additionally, chassis designs are becoming increasingly sophisticated to accommodate advanced braking layouts and strategically placed fuel tanks or batteries, optimising balance and safety. The integration of alternative fuels such as hydrogen and electric batteries into these designs marks a shift towards sustainability, reflecting the sector's commitment to reducing environmental impact. A thorough understanding of these design principles is therefore paramount for specialists in the domain of heavy vehicles.

The aim of this unit is to deepen students' understanding of the construction and operation of critical systems in heavy vehicles, such as braking, suspension and transmission systems. It will guide students through an examination of the various chassis designs used for both passenger and goods vehicles, while also detailing the layout and operation of braking systems and the strategic placement of fuel tanks.

Prior knowledge required for this unit builds on the foundations laid in the *Unit 4113 Heavy Vehicles I*, enhancing students' grasp of the operating principles of these systems. This progression is designed to equip students with the comprehensive technical insight necessary for specialising in the domain of heavy vehicles, preparing them for advanced challenges in automotive engineering.

Upon successful completion of this unit, students will be able to describe in detail the function and operation of key systems such as braking, suspension and transmission, and understand how these systems interrelate to ensure the safe operation of heavy vehicles. They will gain insights into the design variations and layout considerations to assess and optimise vehicle safety and performance, which will prepare them to address complex engineering challenges in the automotive industry effectively.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Investigate heavy vehicle chassis design principles and layouts

LO2 Explore the operating principles of heavy vehicle engine and clutch systems

LO3 Assess the application and operation of heavy vehicle braking systems

LO4 Investigate heavy vehicle suspension systems.

Essential Content

LO1 **Investigate heavy vehicle chassis design principles and layouts.**

Types of heavy vehicle:

Goods vehicles

Passenger vehicles

Agricultural and industrial vehicles

Specialist commercial vehicles

A selection of industry case studies of different heavy vehicle types.

Chassis design layouts:

Chassis classifications

Ladder frame

Integral frame

Semi-integral frame

Location of systems

Types and causes of loading

Load distribution in various body systems.

LO2 **Explore the operating principles of heavy vehicle engine and clutch systems**

Engines:

Piston displacement and capacity

Torque and power ratings

Efficiency

Combustion processes

Working cycles

Ignition systems.

Operating principles of clutches:

Torque calculations

Power flow

Fluid flywheels

Faults and symptoms of faults

Self-adjusting clutches

Operating principles of gearboxes.

LO3 **Assess heavy vehicle braking systems.**

Braking system components:

Air-brake system components

Hydraulic brake system components

Disc and drum brakes

Brake lining materials

Drive shaft mounted brakes.

Factors to consider in brake design:

Pedal forces and travel

Thermal effects

Parking brake design

Auxiliary braking systems

Electronically controlled brake and spring systems: ABS, EBS, ECAS, TEBS

Dynamics of braking systems

Breaking force distribution

Braking force calculation

Trailer synchronisation

Legal frameworks, regulations and policies, professional standards, requirements and compliance (e.g. region specific and application).

LO4 **Investigate heavy vehicle suspension systems**

Suspension design and configuration:

Leaf spring suspension

Spring suspension

Fluid and pneumatic damping systems

Axle lift systems

Suspension linkage systems

Suspension geometry.

Issues linked to suspension design and configuration:

Effects of unsprung masses

Pitch and yaw

Effects of road surfaces and driving conditions.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate heavy vehicle chassis design principles and layouts		
P1 Discuss chassis design requirements for a range of different types of heavy vehicle. **P2** Investigate the layouts and designs of chassis for given types of heavy vehicle.	**M1** Assess how chassis designs for given types of heavy vehicle are influenced by the use of the vehicle.	**D1** Evaluate chassis design and layouts for a range of types of heavy vehicle with respect to the function and use of the vehicle.
LO2 Explore the operating principles of heavy vehicle engine and clutch systems		
P3 Assess how design factors affect the efficiency of heavy vehicle engines. **P4** Explore the design considerations for heavy vehicle clutches.	**M2** Analyse how engine and clutch system design can affect the efficiency of heavy vehicle operations.	**D2** Evaluate the function, operation and efficiency of engines and clutches for passenger and goods vehicles.

Pass	Merit	Distinction
LO3 Assess heavy vehicle braking systems		
P5 Assess the types and configurations of heavy vehicle braking systems. **P6** Discuss the factors that affect the function and operation of heavy vehicle braking systems.	**M3** Assess how the design and configuration of heavy vehicle braking systems contributes to the safe operation of vehicles.	**D3** Evaluate the use of air and hydraulic braking systems for a passenger and goods vehicles.
LO4 Investigate heavy vehicle suspension systems		
P7 Investigate the alternative suspension systems that can be used for heavy passenger and goods vehicles. **P8** Assess the factors that affect the function and operation of heavy vehicle suspension systems.	**M4** Assess the function, configuration and use of alternative types of suspension system for heavy passenger and goods vehicles.	**D4** Evaluate the benefits and drawbacks of different types of suspension system for heavy passenger and goods vehicles.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Textbooks

Belousov, B. and Popov, S. (2014) *Heavy-Duty Wheeled Vehicles: Design, Theory, Calculations*. SAE International.

Bosch Rexroth (2021) *Hydraulics Handbook, Volume 1: Principles and Components*. Stuttgart: Bosch Rexroth AG.

Bosch Rexroth (2021) *Hydraulics Handbook, Volume 2: System Design and Application*. Stuttgart: Bosch Rexroth AG.

Bosch Rexroth (2021) *Hydraulics Handbook, Volume 3: Maintenance and Troubleshooting*. Stuttgart: Bosch Rexroth AG.

Brake Systems Engineers (2021) *Comprehensive Guide to Modern Braking Systems*. London: Brake Systems Publications.

Dempsey, A. (2022) *Modern Hydraulic Systems: Design, Operation, and Maintenance*. New York: McGraw Hill Education.

Dixon, J.C. (2022) *Braking Systems and Brake Design: An Engineering Perspective*. Oxford: Butterworth-Heinemann.

Genta, G. and Morello, L. (2019) *The Automotive Chassis: Volume 1: Components Design*. Springer Nature.

Genta, G. and Morello, L. (2019) *The Automotive Chassis: Volume 2: System Design*. Springer Nature.

Haldex (2020) *Brake Systems Manual: Design, Operation, and Maintenance*. Stockholm: Haldex Group.

Hilgers, M. (2023) *Chassis and Axles*. Springer Nature.

Knorr-Bremse (2021) *Fundamentals of Brake Systems: A Technical Manual*. Munich: Knorr-Bremse AG.

Kumar, P. and Singh, R. (2020) *Advanced Hydraulics and Pneumatics Systems*. New Delhi: Springer India.

Wagner, D. (2021) *Braking Technology: Innovations and Applications*. Stuttgart: Springer-Verlag.

Journals and articles

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills and subject specific knowledge and skills as part of unit level delivery.

'Design and analysis of heavy commercial vehicle chassis through material optimization', *International Journal of Engineering Trends and Technology*. Available at: https://www.ijettjournal.org/.

'Design, analysis and optimization of heavy vehicle chassis using finite element analysis', *ResearchGate.* Available at: https://www.researchgate.net/publication/341434935_Design_Analysis_and_Optimization_of_Heavy_Vehicle_Chassis_Using_Finite_Element_Analysis.

'Design and analysis of heavy duty vehicle truck chassis', *ResearchGate.* Available at: https://www.researchgate.net/publication/341519129_Design_and_analysis_of_heavy_duty_vehicle_truck_chassis.

'IJIR paper template', *International Journal of Creative Research Thoughts.* Available at: https://www.ijcrt.org/.

IRCobi *The New In-Depth, At-the-Scene, Accident Investigation Database in India.* Available at: https://www.ircobi.org/new-accident-investigation-database-in-india.

ITAI *Good Practice in Forensic Road Collision Investigation.* Available at: https://www.itai.org/goodpracticeinforensicroadcollisioninvestigation.pdf.

Links

This unit links to the following related units:

Unit 4091: Automotive Fundamentals

Unit 4092: Vehicle Dynamics and Performance

Unit 4098: Hybrid and Electric Vehicle Technologies

Unit 4113: Heavy Vehicles I

Unit 5058: Automotive Structures and Materials

Unit 5063: Further Hybrid and Electric Vehicle Technologies

5.0 HN Global: Additional Resources

Additional resources for several units can be accessed via HN Global platform: https://hnglobal.highernationals.com/. These include various websites, indicative equipment, and example lab facilities to be used as indicative reference only in creating delivery materials and to support overall qualification delivery.

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