BTEC

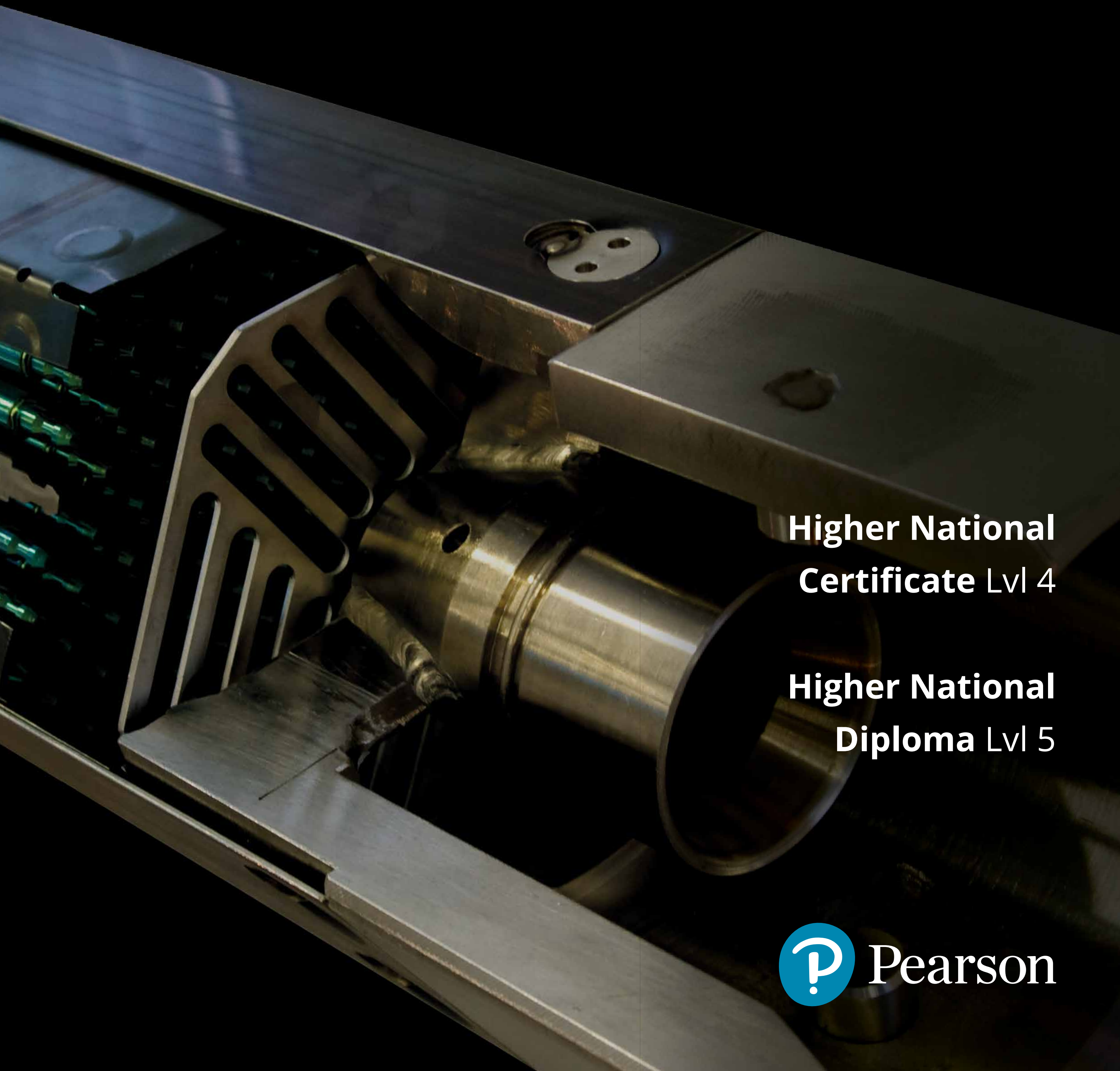
HIGHER NATIONALS

Nuclear Engineering

Specification

First Teaching from September 2017

First Certification from 2018



Higher National Certificate Lvl 4

Higher National Diploma Lvl 5

Pearson

About Pearson

We are the world's leading learning company operating in countries all around the world. We provide content, assessment and digital services to learners, educational institutions, employers, governments and other partners globally. We are committed to helping equip learners with the skills they need to enhance their employability prospects and to succeed in the changing world of work. We believe that wherever learning flourishes so do people.

References to third-party material made in this specification are made in good faith. We do not endorse, approve or accept responsibility for the content of materials, which may be subject to change, or any opinions expressed therein. (Material may include textbooks, journals, magazines and other publications and websites.)

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

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Summary of changes in Pearson BTEC Higher Nationals in Nuclear Engineering Issue 6

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<tr><th>Summary of changes made between previous issue and this current issue</th><th>Page number</th></tr>
<tr><td>Unit 1

Corrected assessment criteria (LO2) – Clarified and improved grammar in P5 and M3
Amended assessment criteria (LO3)
Amended P7 to ensure holistic assessment and scaffolding principle
Deleted assessment criteria M5
Amended M4 to ensure holistic assessment and scaffolding principle
Amended D3 to clarify requirement
Amended assessment criteria (LO4)
Renumbered M6 to M5
Clarified and improved grammar of M5 and D4 to ensure holistic assessment and scaffolding principle</td><td>71-77</td></tr>
<tr><td>Unit 2

Corrected LO2 – removed the following ‘<s>by using appropriate computer software packages</s>’

Corrected Essential Content (LO1) – replaced term ‘circular’ with ‘trigonometric’

Insertion into Essential Content (LO2) – inserted the line ‘Charts, graphs and tables to present data’

Amended Essential Content (LO4) – Revised section on ‘Integration of functions’

Amended Assessment Criteria (LO1)
inserted ‘logarithmic’ into P3
removed ‘statistical’ from D1
Amended Assessment Criteria (LO2) – Clarified P4 to ensure holistic assessment and scaffolding principle

Amended Assessment Criteria (LO3) – Corrected requirement in M3

Amended Assessment Criteria (LO4) – Replaced term ‘circular’ with ‘trigonometric’ in P8</td><td>78-83</td></tr>
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Unit 3 Corrected LO1 – Replaced term '*computational*' with '*qualitative*' Amended Essential Content (LO2) – Replaced term '*objects*' with '*beams*' and inserted term '*uniformly*' Amended Essential Content (LO3) – Replaced term '*plastics*' with '*polymers*' Amended Assessment Criteria (LO1) – Corrected command verb and replaced term '*computational*' with '*qualitative*' in D1 Amended Assessment Criteria (LO2) • Clarified P3 • Amended P5 to ensure holistic assessment and scaffolding principle • Clarified and amended D2 to ensure holistic assessment and scaffolding principle Amended Assessment Criteria (LO3) • Replaced 'electrical and magnetic' with 'electromagnetic' in M3 • Clarified requirement in D3 Amended Assessment Criteria (LO4) – Clarified P8, P9, P10 and D4 to ensure holistic assessment and scaffolding principle	84-89
Unit 19 Corrected LO1 – removed term '~~*simple*~~' Corrected LO2 – removed term '~~*simple*~~' Insertion into Essential Content (LO3) – Inserted the following '*Simple semiconductor applications:* *Diodes: AC-DC rectification, light emitting diode, voltage regulation Transistors: switches and signal amplifiers.*' Amended Assessment Criteria (LO1) – Amended D1 to ensure holistic assessment and scaffolding principle Amended Assessment Criteria (LO2, LO3 and LO4) – Amended P2, M2, M3, M4, D2, D3 and D4 to ensure holistic assessment and scaffolding principle	177-183

Unit 39 Amended Essential Content (LO2) – Inserted '*and 3x3*' in Matrix Methods section Amended Assessment Criteria (LO1) – Changed command verb in M1 Amended Assessment Criteria (LO2) • Corrected command verb in P4 • Inserted 'for a 3x3 matrix' into M2 to ensure holistic assessment and scaffolding principle • Amended to ensure holistic assessment and scaffolding principle Amended Assessment Criteria (LO3) – Changed command verb in D3 Amended Assessment Criteria (LO3) • Amended command verbs in P9 and P10 • Amended to ensure holistic assessment and scaffolding principle	261-267
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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. Introduction

BTEC is the world's most successful and best-loved applied learning brand, and it has been engaging students in practical, interpersonal and thinking skills for more than thirty years.

BTECs are work-related qualifications for students taking their first steps into employment, or for those already in employment and seeking career development opportunities. BTECs provide progression into the workplace either directly or via study at university and are also designed to meet employers' needs. Therefore, Pearson BTEC Higher National qualifications are widely recognised by industry and higher education as the principal vocational qualification at Levels 4 and 5.

When redeveloping the Pearson BTEC Higher National qualifications in Nuclear Engineering, we collaborated with a wide range of students, employers, higher education providers, colleges and subject experts, to ensure that the new qualifications meet their needs and expectations. We also worked closely with the Engineering Council guidelines for Level 3 and Level 6 and the relevant Professional Bodies, to ensure alignment with recognised professional standards and the correct level of learning.

There is now a greater emphasis on employer engagement and work readiness. The new BTEC Higher National qualifications in Nuclear Engineering are designed to reflect this increasing need for high-quality professional and technical education pathways at Levels 4 and 5. These qualifications provide students with a clear pathway to employment, appropriate support during employment and a recognised progression route to gain the further learning required at Level 6 to achieve Incorporated Engineer (IEng) registration or to the final stages of a degree.

1.1 The Student Voice

Students are at the heart of what we do. That is why, from the outset, we consulted with students in the development of these qualifications. We involved them in writing groups, sought their feedback, and added their voices and views to those of other stakeholders.

The result, we believe, are qualifications that will meet the needs and expectations of students worldwide.

1.2 Why choose Pearson BTEC Higher Nationals?

Pearson BTEC Higher Nationals are designed to help students secure the knowledge skills and behaviours needed to succeed in the workplace. They represent the latest in professional standards and provide opportunities for students to develop behaviours for work, for example by undertaking a group project, or responding to a client brief. A student may even achieve exemption from professional or vendor qualifications, or student membership of selected professional bodies, to help them on their journey to professional competence.

At the same time the BTEC Higher Nationals are intended to keep doors open for future study should a student wish to progress further in their education after their level 5 study. They do this by allowing space for the development of higher education study skills, such as the ability to research. Clear alignment of level of demand with the Framework for Higher Education qualification descriptors at level 4 and 5 means that students wishing to progress to level 6 study should feel better prepared. The Pearson BTEC Higher Nationals address these various requirements by providing:

- A range of core, optional and specialist units, each with a clear purpose, so there is something to suit each student's choice of programme and future progression plans.
- Fully revised content that is closely aligned with the needs of employers, professional bodies, vendors and higher education for a skilled future workforce.
- The opportunity to develop transferable skills useful for work and for higher education, including research skills, the ability to meet deadlines and communication skills.
- Learning Outcomes mapped against Professional Body standards and vendor accreditation requirements, where appropriate.
- Assessments and projects chosen to help students progress to the next stage (this means some are set by the centre to meet local needs, while others are set by Pearson). Students are required to apply their knowledge to a variety of assignments and activities, with a focus on the holistic development of practical, interpersonal and higher level thinking skills.
- An approach to demand at level 4 and 5 which is aligned with the Framework for Higher Education Qualifications (FHEQ).
- Support for student and tutors including Schemes of Work and Example Assessment Briefs.

1.3 HN Global

Pearson BTEC Higher Nationals are supported by a specially designed range of digital resources, to ensure that tutors and students have the best possible experience during their course. These are available from the HN Global website http://www.highernationals.com/.

With HN Global, tutors can access programme specifications which contain useful information on programme planning and quality assurance processes. Tutors can also view Schemes of Work and Example Assessment Briefs, helping them create meaningful courses and assessments. HN Global also allows tutors to create and annotate reading lists for their students and also keep up-to-date on the latest news regarding HN programmes.

1.4 Qualification titles

Pearson BTEC Level 4 Higher National Certificate in Nuclear Engineering

Specialist pathways are included within brackets in the qualification title:

- Pearson BTEC Level 4 Higher National Certificate in Nuclear Engineering (Electrical and Electronic)
- Pearson BTEC Level 4 Higher National Certificate in Nuclear Engineering (Mechanical)

1.5 Qualification codes

Regulated Qualifications Framework (RQF) Qualification number:

- Pearson BTEC Level 4 Higher National Certificate in Nuclear Engineering: 6603/0491/1
- Pearson BTEC Level 5 Higher National Diploma in Nuclear Engineering: 603/0496/0

1.6 Awarding organisation

Pearson Education Ltd

1.7 Key features

Pearson BTEC Higher National qualifications in Nuclear Engineering offer:

- a stimulating and challenging programme of study that will be both engaging and memorable for students;
- the essential subject knowledge that students need to progress successfully within or into the world of work or onto further study;
- a simplified structure: students undertake a substantial core of learning, required by all engineers, with limited specialism in the Higher National Certificate, building on this in the Higher National Diploma, with further specialist and optional units linked to their specialist area of study;
- two discipline-specific pathways (Electrical and Electronic and Mechanical) at Level 4 and one broad-based pathway (Nuclear Engineering) at Level 5, which reflect industries' needs for engineers skilled in one or other of these two areas, prior to Level 5 specialisation within Nuclear Engineering, so there is something to suit each student's preference for study and future progression plans;
- refreshed content that is closely aligned with employer, Professional Body and higher education needs;
- assessments that consider cognitive skills (what students know) along with affective and applied skills (respectively how they behave and what they can do);
- unit-specific grading and Pearson-set assignments;
- a varied approach to assessment that supports progression to Level 6 and also allows centres to offer assessment relevant to the local economy, thereby accommodating and enhancing different learning styles;
- quality assurance measures – as outlined in *sections 6 and 7* of this Programme Specification – to ensure that all stakeholders (e.g. Professional Bodies, universities, businesses, colleges and students) can feel confident in the integrity and value of the qualifications;
- a qualification designed to meet the needs and expectations of students aspiring to work in an international setting.

Qualification frameworks

Pearson BTEC Higher National qualifications are designated higher education qualifications in the UK. They are aligned to the Framework for Higher Education Qualifications (FHEQ) in England, Wales and Northern Ireland, and Quality Assurance Agency (QAA) Subject Benchmark Statements. These qualifications are part of the UK Regulated Qualifications Framework (RQF).

1.8 Collaborative development

Students completing their BTEC Higher Nationals in Nuclear Engineering will be aiming to go on to employment or progress to a final year at university. Therefore, it was essential that we developed these qualifications in close collaboration with experts from Professional Bodies, businesses and universities, and with the providers who will be delivering the qualifications.

We are very grateful to all the university and further education tutors, employers, Professional Body representatives and other individuals who have generously shared their time and expertise to help us develop these new qualifications. Employers and Professional Bodies involved have included:

- Alstom
- BMW
- Eaton
- GEN 2
- Jaguar Land Rover
- Railtrack
- Siemens
- UAE Military Logistics Support
- Engineering Council
- Royal Aeronautical Society
- Royal Academy of Engineering
- SEMTA
- Society of Operations Engineers
- The Institution of Engineering and Technology
- The Institute of the Motor Industry
- NFEC (National Forum of Engineering Centres).

Higher education providers that have collaborated with us include:

- Aston University
- Birmingham Metropolitan College
- Blackpool and Fylde College
- Bridgwater College
- Brunel University
- Coventry University College
- University of Derby
- St Helens College
- Teesside University
- UCL
- Warwickshire College.

1.9 Professional Body consultation and approval

Qualifications in engineering within the UK are referenced against the Engineering Council UK specifications which set standards at Level 3, 6 and 8.

The Pearson BTEC Higher Nationals in Nuclear Engineering are set at Level 4 and 5 and have been written with reference to the engineering council specification for Levels 3 and 6. The content and level have been written following advice from the Professional Bodies listed in section 1.7 and are intended to exempt holders of this qualification from the Level 4 and 5 requirements of these bodies and articulate with the Level 6 engineering degree courses.

Holders of a BTEC Higher National in Nuclear Engineering meet the academic requirements for the Engineering Council Engineering Technician Standard (ENGTech).

2. Programme purpose and objectives

2.1 Purpose of the BTEC Higher Nationals in Nuclear Engineering

The purpose of the BTEC Higher Nationals in Nuclear Engineering is to develop students as professional, self-reflecting individuals able to meet the demands of employers in the rapidly evolving nuclear sector and adapt to a constantly changing world. The qualifications also aim to widen access to higher education and enhance the career prospects of those who undertake them.

Nuclear Engineers are required to have the Level 4 skills, knowledge and techniques applicable to either Electrical and Electronic or Mechanical before progressing to Level 5 where they will decide which options reflect their career aspirations within the nuclear reactor industry. These choices include reactor technology and generation of electric power, reactor safety or waste management and recycling, or a combination which offers a more general programme. These requirements are reflected in the two pathways offered at Level 4 (Electrical and Electronic and Mechanical) and the single pathway at Level 5.

2.2 Objectives of the BTEC Higher Nationals in Nuclear Engineering

The objectives of the BTEC Higher Nationals in Nuclear Engineering are as follows:

- to provide students with the core knowledge, skills and techniques that all engineers require, irrespective of future specialism, to achieve high performance in the engineering profession;
- to build a body of specialist knowledge, skills and techniques to be successful in a range of careers in Nuclear Engineering at the Associate Engineer or Operational Engineer level;
- to develop the skills necessary to fault-find and problem-solve in a timely, professional manner, reflecting on their work and contributing to the development of the process and environment they operate within;
- to understand the responsibilities of the engineer within society and work with integrity, with regard for cost, sustainability and the rapid rate of change experienced in world-class engineering;

- to provide opportunities for students to enter or progress in employment within the nuclear engineering sector, or progress to higher education qualifications such as degrees and honours degrees in nuclear engineering by balancing employability skills with academic attainment;
- to provide opportunities for students to make progress towards achieving internationally recognised registration with a professional body regulated by the Engineering Council;
- to allow flexibility of study and to meet local or specialist needs.

We aim to meet these objectives by:

- providing a thorough grounding in general and nuclear engineering principles at Level 4, based on the student or employer preference for electrical and electronic or mechanical emphasis before progressing through a range of specialist progression options at Level 5 relating to individual professions within the nuclear engineering sector;
- equipping individuals with the essential qualities of an engineer, including integrity, regard for cost and sustainability, as they apply to a range of roles and responsibilities within the nuclear sector;
- enabling progression to a university degree by supporting the development of academic study skills and the selection of appropriate units for study at Level 5;
- enabling progression to further professional qualifications in nuclear engineering disciplines by mapping the units studied to the requirements of the professional bodies applicable to that discipline;
- supporting a range of study modes and timeframes for completion of the qualifications.

Who is this qualification for?

The BTEC Higher National qualifications in Nuclear Engineering are aimed at students wanting to continue their education through applied learning. Higher Nationals provide a wide-ranging study of the nuclear sector and are designed for students who wish to pursue a career in nuclear engineering. In addition to the skills, knowledge and techniques that underpin the study of the sector, Pearson BTEC Higher Nationals in Nuclear Engineering give students experience of the breadth and depth of the sector that will prepare them for employment, progression within employment or further study.

2.3 Aims of the Level 4 Higher National Certificate in Nuclear Engineering

The Level 4 Higher National Certificate in Nuclear Engineering offers students two pathways: Nuclear Engineering (Electrical and Electronic) or Nuclear Engineering (Mechanical), which provide a broad introduction to the respective subject area via a mandatory core of learning, while allowing for the acquisition of some pathway-specific skills and experience through the Specialist and Optional Units. A general appreciation of nuclear technology is provided through one of the Specialist Units. This effectively builds underpinning core skills while preparing the student for more intense subject specialisation at Level 5. Students will gain a wide range of sector knowledge tied to practical skills gained in research, self-study, directed study and workplace activities.

At Level 4 students develop a broad knowledge and awareness of key aspects of the engineering sector through four Core Units, including one unit assessed by a Pearson-set assignment. The Core Units are:

1: Engineering Design

2: Engineering Mathematics

3: Engineering Science

4: Managing a Professional Engineering Project*

*Unit 4: Managing a Professional Engineering Project is also the Pearson-set assignment unit.

Nuclear Engineering students study the four mandatory Core Units, three Specialist Units and an additional Optional Unit.

Graduates successfully completing the Higher National Certificate will be able to demonstrate a sound knowledge of the basic concepts of engineering and the nature of the underpinning concepts of nuclear engineering. They will be able to communicate accurately and appropriately and they will have the qualities of personal responsibility needed for employment. They will have developed a range of transferable skills to ensure effective team working, independent working with growing fault-finding and problem-solving strategies, and organisational awareness. They will be adaptable and flexible in their approach to work, showing resilience under pressure and the ability to meet challenging targets within a reasonable, pre-set, timeframe. They will also demonstrate regard for the ethical responsibilities of the engineer, for cost and for the importance of protecting and sustaining the environment.

2.4 Aims of the Level 5 Higher National Diploma in Nuclear Engineering

The Level 5 Higher National Diploma in Nuclear Engineering offers a single pathway for Level 4 students from the Electrical and Electronic and Mechanical pathways at Level 4, designed to support progression into relevant occupational areas (including reactor technology and generation of electric power, reactor safety or waste management and recycling) or onto degree-level study. This pathway is linked to professional body standards (where appropriate) and can provide progression towards professional status or entry to the later stages of an appropriate degree.

Holders of the Level 5 Higher National Diploma will have developed a sound understanding of the principles in their field of study, and will have learned to apply those principles more widely. Through this they will have learned to evaluate the appropriateness of different approaches to solving problems. They will be able to perform effectively in their chosen field and will have the qualities necessary for employment in situations requiring the exercise of personal responsibility and decision making.

At Level 5 students continue to build on the essential skills, knowledge and techniques necessary for all engineers while working through a larger number of subject-specific Specialist and Optional Units. The two mandatory Core Units at Level 5 are:

34: Research Project

*35: Professional Engineering Management**

**Unit 35: Professional Engineering Management* is also the Pearson-set assignment unit.

Nuclear Engineering students study the two mandatory Core Units, one Specialist Unit and an additional four Optional Units.

2.5 What could these qualifications lead to?

The Level 4 Higher National Certificate provides a solid grounding in engineering, which students can build on should they decide to continue their studies beyond the Certificate stage. The Level 5 Higher National Diploma allows students to specialise by committing to specific career paths and progression routes to degree-level study.

On successful completion of the Level 5 Higher National Diploma, students can develop their careers in the engineering sector through:

- Entering employment
- Continuing existing employment
- Linking with the appropriate Professional Body
- Linking with the appropriate vendor accredited certificates [if appropriate]
- Committing to Continuing Professional Development (CPD)
- Progressing to university.

The Level 5 Higher National Diploma is recognised by Higher Education providers as meeting admission requirements to many relevant nuclear engineering degree programmes.

Students should always check the entry requirements for degree programmes at specific Higher Education providers. After completing a BTEC Higher National Certificate or Diploma, students can also progress directly into employment.

The skills offered as part of the Pearson BTEC Higher National Diploma can provide graduates with the opportunity to work in many different areas of the engineering. Overleaf are some examples of job roles each qualification could lead to.

Pathway	**Typical Job Roles after HNC**	**Typical Job Roles after HND**
Nuclear Engineering	Nuclear Engineering Technician Nuclear Equipment Operations Technician Nuclear Maintenance Operations Technician	Nuclear Engineer Nuclear Reactor Engineer Nuclear Maintenance Project Engineer Nuclear Maintenance Operations Engineer

2.6 Use of maths and English within the curriculum

Those working within the Engineering sector cannot just rely on their technical skills and must ensure **all** skills are relevant to increase employment opportunities. They will be required to communicate appropriately with stakeholders throughout their career and the ability to use maths and English in a professional context is an essential employability skill that must be developed at all levels of study.

Development of essential maths and English skills are embedded throughout these qualifications in accordance with industry requirements. Below are some examples of how these skills are developed in the BTEC Higher Nationals Curriculum:

- Written reports
- Formal presentations
- Informal conversations
- Use of professional, sector-specific language
- Algebraic, logarithmic and circular functions
- Use of analytical and computational methods to evaluate and solve engineering problems
- Use of integral calculus to solve practical problems relating to engineering.

Some aspects of Engineering require high-level maths skills and **we strongly recommend** all students complete diagnostic maths assessments, as well as having A* to C grade and/or 9 to 4 in GCSE Maths (or equivalent) prior to starting the course (see section 3.2 Entry requirements and admissions).

Throughout the programme, students will be using some level of maths within the curriculum. It is vital that all students taking a BTEC Higher National in Engineering are aware that these skills will be required throughout their studies, and as part of learning activities and assessments, to ensure their skills are in line with current industry standards.

2.7 How Higher Nationals in Nuclear Engineering provide both transferable employability skills and academic study skills

Students need both good qualifications and employability skills to enhance their career prospects and personal development. Pearson Higher National Nuclear Engineering qualifications embed throughout the programme the development of key skills, attributes and strengths required by 21st-century employers.

Where employability skills are referred to in this specification, this generally refers to skills in three main categories:

- Cognitive and problem-solving skills: critical thinking; approaching non-routine problems by applying expert and creative solutions; use of systems and digital technology; generating and communicating ideas creatively;
- Intrapersonal skills: self-management; adaptability and resilience; self-monitoring and self-development; self-analysis and reflection; planning and prioritising;
- Interpersonal skills: effective communication and articulation of information; working collaboratively; negotiating and influencing; self-presentation.

Pearson Example Assessment Briefs make recommendations for a range of real or simulated assessment activities, for example group work where appropriate, to encourage the development of collaborative and interpersonal skills or a solution-focused case study to provide an opportunity to develop cognitive skills. There are specific requirements for the assessment of these skills, as relevant, within the assessment grids for each unit. Example Assessment Briefs are for guidance and support only and **must** be customised and amended according to localised needs and requirements. All assignments must still be moderated as per the internal verification process.

Students can also benefit from opportunities for deeper learning, where they are able to make connections between units and select areas of interest for detailed study. In this way, BTEC Higher Nationals provide a vocational context in which students can develop the knowledge and academic study skills required for particular degree courses and progression to university, including:

- active research skills
- effective writing skills
- analytical skills
- critical thinking
- creative problem solving
- decision making
- team building
- exam preparation skills
- digital literacy
- practical design and build skills
- experimental and testing techniques
- competence in assessment methods used in higher education.

To support you in developing these skills in your students, we have developed a map of HE-relevant transferable and academic study skills, available in the *Appendix 3*.

3. Planning your programme

3.1 Delivering the Higher National qualifications

You play a central role in helping your students to choose the right BTEC Higher National qualification.

Assess your students very carefully to ensure that they take the right qualification and the right pathways or Optional Units to allow them to progress to the next stage. You should check the qualification structures and unit combinations carefully when advising students.

You will need to ensure that your students have access to a full range of information, advice and guidance to support them in making the necessary qualification and unit choices. When students are recruited, you need to give them accurate information on the title and focus of the qualification for which they are studying.

3.2 Entry requirements and admissions

Although Pearson do not specify formal entry requirements, as a centre it is your responsibility to ensure that the students you recruit have a reasonable expectation of success on the programme.

For students who have recently been in education, the entry profile is likely to include one of the following:

- A* to C grade and/or 9 to 4 in GCSE Maths (or equivalent) is strongly recommended
- A BTEC Level 3 qualification in Engineering
- A GCE Advanced Level profile that demonstrates strong performance in a relevant subject or adequate performance in more than one GCE subject. This profile is likely to be supported by GCSE grades at A* to C and/or 9 to 4 (or equivalent)
- Other related Level 3 qualifications
- An Access to Higher Education Diploma awarded by an approved further education institution
- Related work experience
- An international equivalent of the above.

Centres may wish to consider applicants' prior learning when considering their acceptance on BTEC Higher Nationals, through Recognition of Prior Learning. (For further information please refer to section 8 of this document.)

English language requirements

Pearson's mission is to help people make more of their lives through learning. For students to be successful on Pearson BTEC Higher National qualifications which are **both** taught and assessed in English, it is critical that they have an appropriate level of English language skills.

The following clarifies the requirements for all centres when recruiting applicants on to new Pearson BTEC Higher National qualifications.

All centres delivering the new Pearson BTEC Higher National qualifications must ensure that all students who are non-native English speakers, and who have not undertaken their final two years of schooling in English, can demonstrate capability in English at a standard equivalent to the levels identified below before being recruited to the programme **where the programme is both taught and assessed in English**:

- Common European Framework of Reference (CEFR) level B2
- PTE **51**
- IELTS **5.5**; Reading and Writing must be at **5.5**
- or equivalent.

It is up to the centre to decide what proof will be necessary to evidence individual student proficiency.

The following clarifies the requirements for all centres when recruiting applicants on to new Pearson BTEC Higher National qualifications which are taught in a language other than English, but are assessed in English.

All centres delivering the new Pearson BTEC Higher National qualifications **wholly or partially** in a language other than English, but who are assessed in English, must ensure that all students can demonstrate capability in English at a standard equivalent to the levels identified below, on completion of the programme:

- Common European Framework of Reference (CEFR) level B2
- PTE **51**
- IELTS **5.5**; Reading and Writing must be at **5.5**
- or equivalent.

It is up to the centre to decide what proof will be necessary to evidence individual student proficiency.

Centre approval

To ensure that centres are ready to assess students and that we can provide the support that is needed, all centres must be approved before they can offer these qualifications. For more information about becoming a centre and seeking approval to run our qualifications please visit the support section on our website (http://qualifications.pearson.com/).

Level of sector knowledge required

We do not set any requirements for tutors, but we do recommend that centres assess the overall skills and knowledge of the teaching team, which should be relevant, up to date and at the appropriate level.

Resources required

As part of your centre approval, you will need to show that the necessary material resources and work spaces are available to deliver BTEC Higher Nationals. For some units, specific resources are required; this is clearly indicated in the unit descriptors.

HN Global support

HN Global is an online resource that supports centre planning and delivery of BTEC Higher Nationals by providing appropriate teaching and learning resources. For further information see *sections 5 and 6* of this Programme Specification.

Modes of delivery

Subject to approval by Pearson, centres are free to deliver BTEC Higher Nationals using modes of delivery that meet the needs of their students. We recommend making use of a wide variety of modes, including:

- Full-time
- Part-time
- Blended learning
- Distance learning.

Recommendations for employer engagement

BTEC Higher Nationals are vocational qualifications and as an approved centre you are encouraged to work with employers on the design, delivery and assessment of the course. This will ensure that students enjoy a programme of study that is engaging and relevant, and which equips them for progression. There are suggestions in section 5.2 about how employers could become involved in delivery and/or assessment, but these are not intended to be exhaustive and there will be other possibilities at a local level.

Support from Pearson

We provide a range of support materials, including Schemes of Work and Example Assessment Briefs, with supporting templates. You will be allocated an External Examiner early in the planning stage to support you with planning your assessments, and there will be training events and support from our Subject Leads.

Student employability

All BTEC Higher Nationals have been designed and developed with consideration of National Occupational Standards, where relevant, and have been mapped to relevant professional body standards.

Employability skills such as team working and entrepreneurialism as well as practical hands-on skills have been built into the design of the learning aims and content. This gives you the opportunity to use relevant contexts, scenarios and materials to enable students to develop a portfolio of evidence demonstrating the breadth of their skills and knowledge in a way that equips them for employment.

3.3 Access to study

This section focuses on the administrative requirements for delivering a BTEC Higher National qualification. It will be of value to Quality Nominees, Programme Leaders and Examinations Officers.

Our policy regarding access to our qualifications is that:

- They should be available to everyone who is capable of reaching the required standards.
- They should be free from any barriers that restrict access and progression.

There should be equal opportunities for all those wishing to access the qualifications. We refer Centres to our Pearson Equality and Diversity Policy, which can be found in the support section of our website (http://qualifications.pearson.com/).

Centres are required to recruit students to Higher National programmes with integrity. They will need to make sure that applicants have relevant information and advice about the qualification, to make sure it meets their needs. Centres should review the applicant's prior qualifications and/or experience to consider whether this profile shows that they have the potential to achieve the qualification. For students with disabilities and specific needs, this review will need to take account of the support available to the student during the teaching and assessment of the qualification. For further guidance and advice please refer to *section 9* on reasonable adjustments.

3.4 Student registration and entry

All students should be registered for the qualification, and appropriate arrangements made for internal and external verification. For information on making registrations for the qualification, you will need to refer to the information manual available in the support section of our website (http://qualifications.pearson.com/).

Students can be formally assessed only for a qualification on which they are registered. If students' intended qualifications change (for example, if a student decides to choose a different specialist pathway), then the centre must transfer the student to the chosen pathway appropriately. Please note that student work cannot be sampled if the student is not registered or is registered on an incorrect pathway.

3.5 Access to assessment

Assessments need to be administered carefully, to ensure that all students are treated fairly, and that results and certification are issued on time, to allow students to move on to chosen progression opportunities.

Our equality policy requires that all students should have equal opportunity to access our qualifications and assessments, and that our qualifications are awarded in a way that is fair to every student. We are committed to making sure that:

- Students with a protected characteristic (as defined in legislation) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic.

- All students achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

Further information on access arrangements can be found on the Joint Council for Qualifications website (http://www.jcq.org.uk/).

3.6 Administrative arrangements for internal assessment

Records

You are required to retain records of assessment for each student. Records should include assessments taken, decisions reached and any adjustments or appeals. Further information on quality and assessment can be found in our UK and international guides available in the support section on our website (http://qualifications.pearson.com/).

We may ask to audit your records, so they must be retained as specified. All student work must be retained for **a minimum of 12 weeks** after certification has taken place.

Reasonable adjustments to assessment

A reasonable adjustment is one that is made before a student takes an assessment, to ensure that he or she has fair access to demonstrate the requirements of the assessments.

You are able to make adjustments to internal assessments to take account of the needs of individual students. In most cases this can be achieved through a defined time extension or by adjusting the format of evidence. We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. You need to plan for time to make adjustments, if necessary.

Further details on how to make adjustments for students with protected characteristics are available on the support section of our website (http://qualifications.pearson.com/).

Special consideration

Special consideration is given after an assessment has taken place for students who have been affected by adverse circumstances, such as illness, and require an adjustment of grade to reflect a normal level of attainment. You must operate special consideration in line with Pearson policy (see previous paragraph). You can provide special consideration related to the period of time given for evidence to be provided or for the format of the assessment (if it is equally valid). You may not substitute alternative forms of evidence to that required in a unit, or omit the application of any assessment criteria to judge attainment. Pearson can only consider applications for special consideration in line with the policy, which can be found in the document linked above.

Please note that your centre must have a policy for dealing with mitigating circumstances if students are affected by adverse circumstances, such as illness, which has resulted in non-submission or a late submission of assessment.

Appeals against assessment

Your centre must have a policy for dealing with appeals from students. These appeals may relate to assessment decisions being incorrect or assessment not being conducted fairly. The first step in such a policy could be a consideration of the evidence by a Programme Leader or other member of the programme team. The assessment plan should allow time for potential appeals after assessment decisions have been given to students. If there is an appeal by a student, you must document the appeal and its resolution. Students have a final right of appeal to Pearson, but only if the procedures that you have put in place have been followed.

Further details of our policy on enquiries and appeals is available on the support section of our website (http://qualifications.pearson.com/).

If your centre is located in England or Wales and the student is still dissatisfied with the final outcome of their appeal s/he can make a further appeal to the Office of the Independent Adjudicator (OIA) by emailing: enquiries@oiahe.org.uk. In Northern Ireland a further appeal may be lodged with the Northern Ireland Public Service Ombudsman (NIPSO) by emailing: nipso@nipso.org.uk.

3.7 Dealing with malpractice in assessment

'Malpractice' means acts that undermine the integrity and validity of assessment or the certification of qualifications, and/or that may damage the authority of those responsible for delivering the assessment and certification. Malpractice may arise or be suspected in relation to any unit or type of assessment within the qualification.

Pearson does not tolerate actions (or attempted actions) of malpractice by students, centre staff or centres in connection with Pearson qualifications. Pearson may impose penalties and/or sanctions on students, centre staff or centres where incidents (or attempted incidents) of malpractice have been proven.

Further details regarding malpractice and advice on preventing malpractice by students, can be found in the support section of our website (http://qualifications.pearson.com/).

In the interests of students and centre staff, centres need to respond effectively and openly to all requests relating to an investigation into an incident of suspected malpractice. The procedures we ask you to adopt when tackling malpractice vary between units that are internally assessed and those that are externally assessed.

Internally assessed units

Centres are required to take steps to prevent malpractice and to investigate instances of suspected malpractice. Students must be given information that explains what malpractice is for internal assessment and how suspected incidents will be dealt with by the centre. Full information on dealing with malpractice and the actions we expect you to take is available on the support section of our website (http://qualifications.pearson.com/).

Pearson may conduct investigations if it is believed that a centre is failing to conduct internal assessment according to Pearson policies. The above document gives further information, provides examples, and details the penalties and sanctions that may be imposed.

Student malpractice

Heads of centres are required to report incidents of any suspected student malpractice that occur during Pearson external assessments. We ask that centres do so by completing *JCQ Form M1* from the Joint Council for Qualifications website (http://www.jcq.org.uk/) and emailing it, along with any accompanying documents, (signed statements from the student, invigilator, copies of evidence, etc.), to the Investigations Team at pqsmalpractice@pearson.com. The responsibility for determining appropriate sanctions or penalties to be imposed on students lies with Pearson.

Students must be informed at the earliest opportunity of the specific allegation and the centre's malpractice policy, including the right of appeal. Students found guilty of malpractice may be disqualified from the qualification for which they have been entered with Pearson.

Tutor/centre malpractice

Heads of centres are required to inform Pearson's Investigations Team of any incident of suspected malpractice by centre staff, before any investigation is undertaken. Heads of centres are requested to inform the Investigations Team by submitting a *JCQ Form M2b* from the Joint Council for Qualifications website (http://www.jcq.org.uk/) with supporting documentation to **pqsmalpractice@pearson.com**. Where Pearson receives allegations of malpractice from other sources (for example, Pearson staff or anonymous informants), the Investigations Team will conduct the investigation directly or may ask the head of centre to assist.

Incidents of maladministration (accidental errors in the delivery of Pearson qualifications that may affect the assessment of students) should also be reported to the Investigations Team, using the same method.

Heads of centres/Principals/Chief Executive Officers or their nominees are required to inform students and centre staff suspected of malpractice of their responsibilities and rights; see *6.15 of JCQ Suspected Malpractice in Examinations and Assessments Policies and Procedures* (www.jcq.org.uk).

Pearson reserves the right in cases of suspected malpractice to withhold the issue of results and/or certificates while an investigation is in progress. Depending on the outcome of the investigation, results and/or certificates may be released or withheld. We reserve the right to withhold certification when undertaking investigations, audits and quality assurance processes. You will be notified within a reasonable period of time if this occurs.

Sanctions and appeals

Wherever malpractice is proven, we may impose sanctions or penalties.

Where student malpractice is evidenced, penalties may be imposed such as:

- disqualification from the qualification;
- being barred from registration for Pearson qualifications for a specified period of time.

If we are concerned about your centre's quality procedures, we may impose sanctions such as:

- working with you to create an improvement action plan;
- requiring staff members to receive further training;
- placing temporary blocks on your certificates;
- placing temporary blocks on registrations of students;
- debarring staff members or the centre from delivering Pearson qualifications;
- suspending or withdrawing centre approval status.

Your centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from heads of centres (on behalf of students and/or members or staff) and from individual members (in respect of a decision taken against them personally). Further information on appeals can be found in our Enquiries and Appeals Policy available in the support section on our website (http://qualifications.pearson.com/).

In the initial stage of any aspect of malpractice, please notify the Investigations Team by email (pqsmalpractice@pearson.com), who will inform you of the next steps.

4. Programme structure

4.1 Units, Credits, Total Qualification Time (TQT) and Guided Learning (GL)

The Higher National Certificate (HNC) is a Level 4 qualification made up of 120 credits. It is usually studied full-time over one year, or part-time over two years.

The Higher National Diploma (HND) is a Level 4 and Level 5 qualification made up of 240 credits. It is usually studied full-time over two years, or part-time over four years.

Pearson would expect that an HND student would have achieved at least 90 credits at Level 4 before progressing to Level 5 units. This allows for the students to submit the remaining 30 credits at Level 4 while undertaking their Level 5 study.

Students undertaking an HND who fail to successfully complete the full qualification may be awarded an HNC, if their credit achievement permits.

BTEC Higher Nationals consist of Core Units, Specialist Units and Optional Units:

- Core Units are mandatory
- Specialist Units are designed to provide a specific occupational focus to the qualification and are aligned to professional body standards
- Required combinations of units are clearly set out in the tables below.

All units are usually 15 credits in value, or a multiple thereof. These units have been designed from a learning time perspective, and are expressed in terms of **Total Qualification Time (TQT)**. TQT is an estimate of the total amount of time that could reasonably be expected to be required for a student to achieve and demonstrate the achievement of the level of attainment necessary for the award of a qualification. TQT includes undertaking each of the activities of Guided Learning, Directed Learning and Invigilated Assessment. Each 15-credit unit approximates to a Total Unit Time of 150 hours and 60 hours of Guided Learning.

Total Qualification Time (TQT) Higher National Certificate (HNC) = 1,200 hours

Total Qualification Time (TQT) Higher National Diploma (HND) = 2,400 hours

Examples of activities which can contribute to TQT include:

- Guided Learning
- Independent and unsupervised research/learning
- Unsupervised compilation of a portfolio of work experience
- Unsupervised e-learning
- Unsupervised e-assessment
- Unsupervised coursework
- Watching a pre-recorded podcast or webinar
- Unsupervised work-based learning.

Guided Learning (GL) is defined as the time when a tutor is present to give specific guidance towards the learning aim being studied on a programme. This definition includes lectures, tutorials and supervised study in, for example, open learning centres and learning workshops. Guided Learning includes any supervised assessment activity; this includes invigilated examination, observed assessment and observed work-based practice.

Total Guided Learning (GL) Higher National Certificate (HNC) = 480 hours

Total Guided Learning (GL) Higher National Diploma (HND) = 960 hours

Some examples of activities which can contribute to Guided Learning include:

- Classroom-based learning supervised by a tutor
- Work-based learning supervised by a tutor
- Live webinar or telephone tutorial with a tutor in real time
- E-learning supervised by a tutor in real time
- All forms of assessment which take place under the immediate guidance or supervision of a tutor or other appropriate provider of education or training, including where the assessment is competence-based and may be turned into a learning opportunity.

4.2 Programme structures

The programme structures specify:

- the total credit value of the qualification;
- the minimum credit to be achieved at the level of the qualification;
- the Core Units;
- the Specialist Units;
- the Optional Units;
- the maximum credit value in units that can be centre-commissioned.

When combining units for a Pearson Higher National qualification, it is the centre's responsibility to make sure that the correct combinations are followed.

Each pathway has a core of units, four at Level 4 and two at Level 5, which are mandatory and cannot be changed or substituted.

All specialist units are also available for selection as optional units in all other pathways.

Pearson BTEC Level 4 Higher National Certificate in Nuclear Engineering

- Qualification credit value: a minimum of 120 credits. This is made up of eight units, each with a value of 15 credits.
- **Total Qualification Time (TQT)** Higher National Certificate (HNC) = 1,200 hours.
- **Total Guided Learning Hours (GLH)** Higher National Certificate (HNC) = 480 hours.
- There is a required mix of Core, Specialist and Optional Units totalling 120 credits. All units are at Level 4.
- In some cases a maximum of 30 credits from a Higher National qualification may be from units designed by the centre and approved by Pearson. Core Units may **not** be substituted and are **mandatory**. For more information please refer to Higher National Commissioned Qualifications.
- Please note that some Specialist Units are available as Optional Units and some Optional Units are available as Specialist Units.

The pathways and unit combinations are as follows (for the list of Optional Units for all pathways at Level 4, please see pages that follow).

Level 4 Higher National Certificate in Nuclear Engineering (Electrical and Electronic) (120 credits)		Unit credit	Level
Core Unit *Mandatory*	**1 Engineering Design**	15	4
Core Unit *Mandatory*	**2 Engineering Maths**	15	4
Core Unit *Mandatory*	**3 Engineering Science**	15	4
Core Unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist Unit *Mandatory*	**19 Electrical and Electronic Principles***	15	4
Specialist Unit *Mandatory*	**22 Electronic Circuits and Devices***	15	4
Specialist Unit *Mandatory*	**33 Fundamentals of Nuclear Power Engineering***	15	4
Optional Unit	**Plus one Optional Unit from general Optional Unit Bank Level 4 (see below)**	15	4

*Specialist Unit also available as an Optional Unit.

Level 4 Higher National Certificate in Nuclear Engineering (Mechanical) (120 credits)		Unit credit	Level
Core Unit *Mandatory*	**1 Engineering Design**	15	4
Core Unit *Mandatory*	**2 Engineering Maths**	15	4
Core Unit *Mandatory*	**3 Engineering Science**	15	4
Core Unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist Unit *Mandatory*	**8 Mechanical Principles**	15	4
Specialist Unit *Mandatory*	**13 Fundamentals of Thermodynamics and Heat Engines***	15	4
Specialist Unit *Mandatory*	**33 Fundamentals of Nuclear Power Engineering***	15	4
Optional Unit	**Plus one Optional Level 4 Unit from Optional Unit Bank Level 4 (see below)**	15	4

*Specialist Unit also available as an Optional Unit.

Optional Unit Bank Level 4		Unit credit	Level
Optional	**5 Renewable Energy**	15	4
Optional	**6 Mechatronics**	15	4
Optional	**7 Machining and Metal Forming Processes**	15	4
Optional	**8 Mechanical Principles***	15	4
Optional	**9 Materials, Properties and Testing**	15	4
Optional	**10 Mechanical Workshop Practices**	15	4
Optional	**11 Fluid Mechanics**	15	4
Optional	**12 Engineering Management**	15	4
Optional	**13 Fundamentals of Thermodynamics and Heat Engines***	15	4
Optional	**14 Production Engineering for Manufacture***	15	4
Optional	**15 Automation, Robotics and PLC**	15	4
Optional	**16 Instrumentation and Control Systems**	15	4
Optional	**17 Quality and Process Improvement***	15	4
Optional	**18 Maintenance Engineering**	15	4
Optional	**19 Electrical and Electronic Principles***	15	4
Optional	**20 Digital Principles**	15	4
Optional	**21 Electrical Machines**	15	4
Optional	**22 Electronic Circuits and Devices***	15	4
Optional	**23 Computer-Aided Design and Manufacture (CAD/CAM)**	15	4

Optional	**29 Electro, Pneumatic and Hydraulic Systems**	15	4
Optional	**30 Operations and Plant Management**	15	4
Optional	**31 Electrical Systems and Fault Finding**	15	4
Optional	**32 CAD for Maintenance Engineers**	15	4
Optional	**33 Fundamentals of Nuclear Power Engineering***	15	4

*Optional Unit also available as a Specialist Unit.

Pearson BTEC Level 5 Higher National Diploma in Nuclear Engineering

The Level 5 Higher National Diploma consists of the Level 4 Higher National Certificate (above) plus an additional 120 credits at Level 5.

- Qualification credit value: a minimum of 240 credits of which 120 credits are at Level 5, and 120 credits are at Level 4 and usually attained via the HNC
- **Total Qualification Time (TQT)** Higher National Diploma (HND) = 2,400 hours
- **Total Guided Learning Hours (GLH)** Higher National Diploma (HND) = 960 hours
- There is a required mix of Core, Specialist and Optional Units for each pathway. The Core Units required for each Level 5 pathway (in addition to the Specialist Units) are 34 Research Project which is weighted at 30 credits, and 35 Professional Engineering Management, weighted at 15 credits
- The requirements of the Higher National Certificate (or equivalent) have to be met. In some cases a maximum of 60 credits can be imported from another RQF Pearson BTEC Higher National qualification and/or from units designed by the centre and approved by Pearson. Core Units and Specialist Units may **not** be substituted
- Please note that some Specialist Units are available as Optional Units and some Optional Units are available as Specialist Units.

The pathways and unit combinations are as follows (for the list of Optional Units for all pathways at Level 5, please see pages that follow).

Level 5 Higher National Diploma in Nuclear Engineering (240 credits)					
Unit type	**Level 4 Pathway units (Electrical and Electronic)**		**Level 4 Pathway units (Mechanical)**	Unit credit	Level
Core Unit *Mandatory*	**1 Engineering Design**		**1 Engineering Design**	15	4
Core Unit *Mandatory*	**2 Engineering Maths**		**2 Engineering Maths**	15	4
Core Unit *Mandatory*	**3 Engineering Science**		**3 Engineering Science**	15	4
Core Unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**		**4 Managing a Professional Engineering Project (Pearson-set)**	15	4

Specialist Unit *Mandatory*	**19 Electrical and Electronic Principles**		**8 Mechanical Principles**	15	4
Specialist Unit *Mandatory*	**22 Electronic Circuits and Devices**		**13 Fundamentals of Thermodynamics and Heat Engines**	15	4
Specialist Unit *Mandatory*	**33 Fundamentals of Nuclear Power Engineering**		**33 Fundamentals of Nuclear Power Engineering**	15	4
Optional Unit	**Plus one Optional Unit from Optional Unit Bank Level 4 (see above)**		**Plus one Optional Unit from Optional Unit Bank Level 4 (see above)**	15	4
Core Unit *Mandatory*	**34 Research Project**			30	5
Core Unit *Mandatory*	**35 Professional Engineering Management (Pearson-set)**			15	5
Specialist Unit *Mandatory*	**39 Further Mathematics***			15	5
Optional Unit	**Plus one Optional Unit from Level 5 optional bank Group D (see below)**			15	5
Optional Unit	**Plus one Optional Unit from Level 5 optional bank Group D (see below)**			15	5
Optional Unit	**Plus one Optional Unit from Level 5 optional bank Group D (see below)**			15	5
Optional Unit	**Plus one Optional Unit from Level 5 optional bank Group D or Level 5 General Optional Unit bank (see below)**			15	5

*Specialist Unit also available as an Optional Unit.

Higher National Diploma Optional Level 5 Unit Bank		Unit credit	Level
Group D			
Optional Unit	**65 Nuclear Reactor Operations**	15	5
Optional Unit	**66 Nuclear Reactor Chemistry**	15	5
Optional Unit	**67 Nuclear Radiation Protection Technology**	15	5
Optional Unit	**68 Nuclear Reactor Materials**	15	5
Optional Unit	**69 Nuclear Fuel Cycle Technology**	15	5
Optional Unit	**70 Nuclear Decommissioning and Radioactive Waste Management Technology**	15	5
Optional Unit	**71 Nuclear Criticality Control**	15	5
Optional Unit	**72 Nuclear Safety Case Development**	15	5

Level 5 General Optional Unit bank			
Optional Unit	**36 Advanced Mechanical Principles**	15	5
Optional Unit	**37 Virtual Engineering***	15	5
Optional Unit	**38 Further Thermodynamics**	15	5
Optional Unit	**39 Further Mathematics***	15	5
Optional Unit	**40 Commercial Programming Software**	15	5

Optional Unit	**41 Distributed Control Systems**	15	5
Optional Unit	**42 Further Programmable Logic Controllers (PLCs)**	15	5
Optional Unit	**43 Further Electrical Machines and Drives**	15	5
Optional Unit	**44 Industrial Power, Electronics and Storage***	15	5
Optional Unit	**45 Industrial Systems***	15	5
Optional Unit	**46 Embedded Systems**	15	5
Optional Unit	**47 Analogue Electronic Systems**	15	5
Optional Unit	**48 Manufacturing Systems Engineering***	15	5
Optional Unit	**49 Lean Manufacturing***	15	5
Optional Unit	**50 Advanced Manufacturing Technology***	15	5
Optional Unit	**51 Sustainability**	15	5
Optional Unit	**52 Further Electrical, Electronic and Digital Principles**	15	5
Optional Unit	**53 Utilisation of Electrical Power**	15	5
Optional Unit	**54 Further Control Systems Engineering**	15	5
Optional Unit	**63 Industrial Services**	15	5
Optional Unit	**64 Thermofluids***	15	5

*Optional Units also used as Specialist Units.

Meeting local needs and centre-devised units

Centres should note that the qualifications set out in these specifications have been developed in consultation with centres, employers and relevant professional organisations.

The units are designed to meet the skill needs of the sector and the Specialist Units allow coverage of the full range of employment within the sector. Centres should make maximum use of the choice available to them within the Specialist Units to meet the needs of their students, as well as the local skills and training needs.

Where centres identify a specific need that cannot be addressed using the units in this specification, centres can seek approval from Pearson to use units from other BTEC Higher National qualifications on the RQF (refer to the Pearson website or your Pearson regional contact for application details). Centres will need to justify the need for importing units from other BTEC Higher National RQF specifications. **Meeting local need applications must be made in advance of delivery by 31 January in the year of registration.**

The flexibility to import standard units from other BTEC Higher National RQF specifications is limited to a maximum of 30 credits in a BTEC HNC qualification and a maximum of 60 credits in any BTEC HND qualification. This is an overall maximum and centres should check the 'Rules of Combination' information for the specific qualification to confirm the actual requirements. These units cannot be used at the expense of the mandatory units in any qualification, nor can the qualification's rules of combination be compromised. The centre must ensure that approved units are used only in eligible combinations.

Alternatively centres can seek approval to use centre-devised units up to the advised maximum amounts for an HNC or HND in the rules of combination to meet a specific need. The centre must provide a clear rationale on the progression benefits to students of taking the unit(s) they are seeking approval for. Pearson will review the application and confirm or deny the request. The centre-devised units can be authored by the centre, subject to Pearson's scrutiny and approval process. Alternatively the centre may seek design and development of these units by Pearson. Applications for approval of centre-devised unit(s) must be made one year in advance of the first year of centre-devised unit(s) delivery. The centre must not deliver and assess centre-devised units until they have been approved by Pearson.

For the **Pearson BTEC Higher National Certificate and Diploma in Nuclear Engineering** the maximum number of credits that can be imported by pathway are as follows:

Qualification	**Pathway**	Import at Level 4	Import at Level 5
HNC Nuclear Engineering	**Electrical and Electronic Engineering**	15	-
	Mechanical Engineering	15	-
HND Nuclear Engineering	**Nuclear Engineering**	15	30

4.3 Pearson-Set Assignments

At both Level 4 and Level 5, as part of the Core units, there are Pearson-set assignments. Each year, Pearson will issue a Theme. Centres will develop an assignment, to be internally assessed, to engage students in work related to the Pearson-set Theme.

At Level 4, students will select a Topic to further define their approach to the Theme and assignment. At Level 5, it is expected that students will define their own Topic, in negotiation with tutors, based on the Pearson-set Theme. For example, from the Higher Nationals in Business:

- Theme: "Corporate Social Responsibility (CSR) and its importance for sustainability and competitive advantage"

Level 4 Topics:

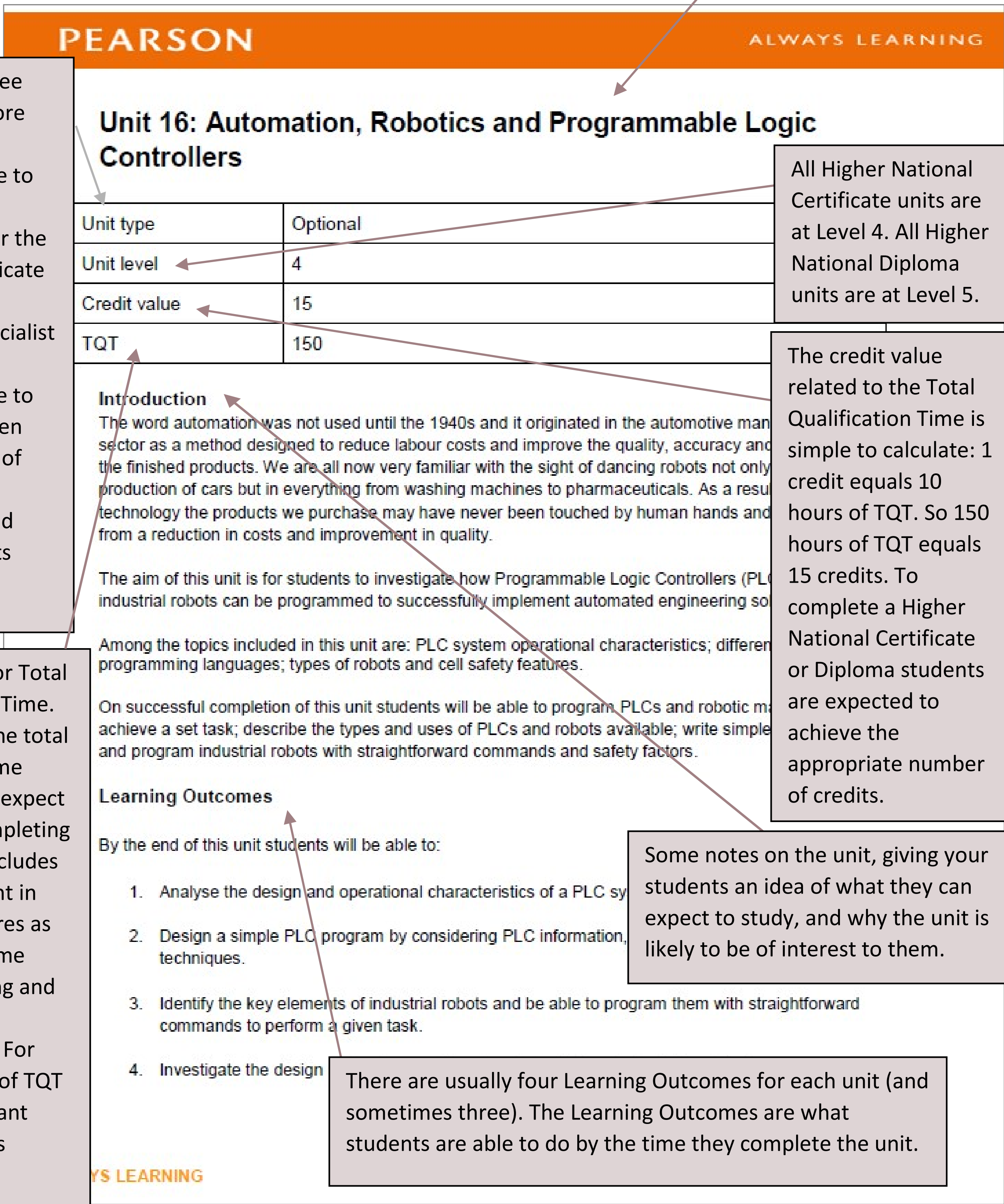
- How to start up a socially responsible company
- The impact of CSR on a functional area (e.g. HR, Marketing, Finance) within an organisation to promote profitability and financial sustainability.
- Implementing CSR activities within organisations to meet sustainability objectives.

Centres can find relevant support in the Pearson-set Assignment Guidance for the units, and the Theme and Topic release documentation, which will be provided for each level.

The aim of the Pearson-set assignments is to provide a common framework for centres to develop work that will allow cross-sector benchmarking, through the standardisation of student work, and identification and sharing of 'best practice' in higher education teaching and learning. Pearson will share the 'best practice' results with all centres. For further information about Pearson-set assignments and assessment, see *section 6.0 Assessment* in this document.

4.4 Annotated unit descriptor

This is how we refer to the individual units of study that make up a Higher National qualification. Students will study and complete the units included in the programme offered at your centre.



The unit title tells your student what the unit is about. At Level 4 they can expect to achieve a complete grounding in the subject and the knowledge and skills required to continue their studies in the subject at Level 5.

PEARSON ALWAYS LEARNING

Unit 16: Automation, Robotics and Programmable Logic Controllers

Unit type	Optional
Unit level	4
Credit value	15
TQT	150

Introduction

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

The aim of this unit is for students to investigate how Programmable Logic Controllers (PL
industrial robots can be programmed to successfully implement automated engineering so

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

On successful completion of this unit students will be able to program PLCs and robotic m
achieve a set task; describe the types and uses of PLCs and robots available; write simple
and program industrial robots with straightforward commands and safety factors.

Learning Outcomes

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

1. Analyse the design and operational characteristics of a PLC sy
2. Design a simple PLC program by considering PLC information, techniques.
3. Identify the key elements of industrial robots and be able to program them with straightforward commands to perform a given task.
4. Investigate the design

YS LEARNING

There are three unit types: Core Units (which students have to complete to achieve either the Level 4 Certificate or Level 5 Diploma; Specialist Units (which students have to complete when studying one of the specialist pathways) and Optional Units which can be chosen.

All Higher National Certificate units are at Level 4. All Higher National Diploma units are at Level 5.

The credit value related to the Total Qualification Time is simple to calculate: 1 credit equals 10 hours of TQT. So 150 hours of TQT equals 15 credits. To complete a Higher National Certificate or Diploma students are expected to achieve the appropriate number of credits.

TQT stands for Total Qualification Time. This means the total amount of time students can expect to spend completing the unit. It includes the time spent in class at lectures as well as the time spent studying and working on assignments. For more details of TQT see the relevant section in this Programme Specification.

Some notes on the unit, giving your students an idea of what they can expect to study, and why the unit is likely to be of interest to them.

There are usually four Learning Outcomes for each unit (and sometimes three). The Learning Outcomes are what students are able to do by the time they complete the unit.

This section covers the content that students can expect to study as they work towards achieving their learning outcomes.

PEARSON ALWAYS LEARNING

Essential Content

LO1 Analyse 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).
Internal architecture.
Different types of programming languages (IEC 61131-3).

LO2 Design a simple PLC program by considering 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).

Test and debug methods.
Systematic testing and debugging methods
Proper application of appropriate testing and debugging methods

LO3 Investigate the key elements of industrial robots and be able to program them with straightforward commands to perform a given task.

Element considerations
Types of robots.
Mobile robotics.
Tools and end effectors.
Programming methods.
Robot manipulators (kinematics, design, dynamics and control, vision systems, user interfaces).

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

Safety
Cell safety features
Operating envelope
Operational modes
User interfaces

ALWAYS LEARNING

When assignments are graded the tutor will refer to this table, which connects the unit Learning Outcomes with the student's work. The unit may be graded Pass', 'Merit' or 'Distinction' level depending on the quality of the student's work.

PEARSON ALWAYS LEARNING

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse 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 construction styles 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 PLC's.	M1 Explain the different types of PLC programming languages available.	
LO2 Design a simple PLC program by considering PLC information, programming and communication techniques.		D2 Design and produce all elements of a PLC program for a given industrial task.
P4 Describe the design elements that have to be considered in the preparation of a PLC programme program P5 Explain how communication connections are correctly used with the PLC.	M2 Examine the methods used for testing and debugging the hardware and software.	
LO3 Investigate the key elements of industrial robots and be able to program them with straightforward commands to perform a given task.		D3 Design and produce a robot program for a given industrial task.
P6 Describe the types of industrial robots and their uses in industry. P7 Describe the types of robot end effectors available and their applications.	M3 Explain 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 to include a full risk assessment.
P8 Describe the safety systems used within an industrial robotic cell.	M4 Explain the systems in place to ensure safe operation of a given industrial robotic cell.	

ALWAYS LEARNING

Recommended books, articles, and online material that support learning.
The programme tutor may suggest alternatives and additions, usually with a local application or relevance.

PEARSON ALWAYS LEARNING

Recommended Resources

PEREZ ANDROVER, E. (2012) Introduction to PLCs: A beginner's guide to Programmable Logic Controllers

BOLTON, W. (2015) Programmable Logic Controllers. 5th Ed. Elsevier.

DAWKINS, N. (2014) Automation and Controls: A guide to Automation, Controls, PLC's and PLC Programming. E-book Ed. Nick Dawkins.

Website-based resources – referencing:

Some units have website links as part of their recommended resources lists. Hyperlinking to these resources directly can be problematic as locations and addresses of resources can change over time. To combat this we have referenced website-based resources as follows:

1. A link to the main page of the website
2. The title of the site
3. The name of the section or element of the website where the resource can be found
4. The type of resource it is. This could be one of the following:
    - Research
    - General Reference
    - Tutorials
    - Training
    - E-Books
    - Report
    - Wiki
    - Article
    - Datasets
    - Development Tool
    - Discussion Forum

Some examples from Computing units have been shown below:

Websites

www.thinkwatson.com Critical Thinking

"Critical Thinking Correlation Studies" (Research)

ipda.org.uk International Professional Development Association (General Reference)

"Guidelines for managing projects - How to organise, plan and control projects." (Report)

4.5 Professional Body collaboration

In redeveloping the BTEC Higher National qualifications in Engineering, we have worked closely with the Engineering Council guidelines and the following professional bodies:

- Royal Aeronautical Society
- Royal Academy of Engineering
- Society of Operations Engineers
- The Institute of Engineering and Technology
- The Institute of the Motor Industry

5. Teaching and learning

The aim of this section is to provide guidance to centres so they can engage students in a dynamic, interactive and reflective learning experience. This experience should effectively prepare students to successfully engage in the assessments, which will measure depth, as well as breadth, of knowledge. Teaching should stimulate academic engagement, develop challenging yet constructive discourse and encourage students to reflect on their own performance in preparation for a professional career. Additionally, centres are encouraged to expose students to autonomous and independent learning, which will facilitate the development of the academic skills, experiences and techniques required as they progress from one level of study to the next.

Centres are encouraged to develop programmes that have a distinctive focus on entry into work, delivering a curriculum that embeds employability, has a strong commitment to ethics and diversity, and introduces students to contemporary as well as seminal research. All teaching and learning should reflect the expectations of employers and society, and be informed and guided by external benchmarks such as professional and statutory bodies. In so doing students completing a Higher National in Engineering will have the attributes, skills, principles and behaviours that will enable them to make a valuable contribution to local, national and international engineering.

The contributions students make to their own experiences, alongside the experience of their peers, is invaluable. Student engagement and the student voice should form a significant aspect of a student's life. Centres are encouraged to gather student opinions on a range of teaching and learning matters, which would be used to inform and enhance future practice within a programme of study and within a centre.

5.1 Delivering quality and depth

A high-quality teaching and learning experience should include qualified and experienced tutors, an interactive and engaging curriculum, motivated and inspired students, and a support system that caters for the pastoral as well as academic interests of students.

In addition to delivering a quality learning experience, centres must also encourage students to have a deeper understanding of the subject where they are able to go beyond the fundamentals of explaining and describing. Students are expected to show they can analyse data and information, make sense of this and then reach evaluative judgements. At the higher levels of study there is an expectation that students will be able to apply a degree of criticality to their synthesis of knowledge. This criticality would come from exposure to appropriate and relevant theories, concepts and models.

One of the reasons for delivering a quality learning experience, which has depth as well as breadth, is the accreditation of the Higher Nationals in Engineering on Ofqual's qualification framework (RQF) and benchmarking to the Framework for Higher Education Qualifications (FHEQ). The first stage of a Higher National in Engineering is the Higher National Certificate (HNC), which is aligned with Level 4 of both frameworks, with the Higher National Diploma (HND) aligned with Level 5. This means that the HNC has the same level of demand and expectations as the first year of a degree programme, with the HND having the same level of demand and expectations as the second year of a degree programme.

Centres are expected to provide a broadly similar experience for students to that on a similar programme at a university. This could mean:

- providing access to a library which has, as a minimum, available copies (physical and/or electronic) of all required reading material;
- access to research papers and journals;
- using a virtual learning environment (VLE) to support teaching;
- working with local employers (see below) to present real-life case studies;
- creating schemes of work that embrace a range of teaching and learning techniques;
- listening to the student voice.

Irrespective of the type of programme on which a student is enrolled, it is highly advisable that students are inducted onto their Higher National programme. This induction should include an introduction to the learning and academic study skills that will be essential in supporting their research and studies, and therefore enhance the learning experience.

An induction programme should consist of the following:

- Course programme overview
- Preparing for lessons
- Effective engagement in lectures and seminars
- Making the most of their tutor
- Assignment requirements
- Referencing and plagiarism
- Centre policies
- Academic study skills

Pearson offer Higher National Global Study Skills to all students – an online toolkit that supports the delivery, assessment and quality assurance of BTECs in centres. This is available on the HN Global website: www.highernationals.com. HN Global provides a wealth of support to ensure that tutors and students have the best possible experience during their course.

In addition, there is a wide range of free-to-access websites that can be used to support students in developing their learning and academic study skills.

5.2 Engaging with employers

Just as the student voice is important, so too is the employer’s. Employers play a significant role in the design and development of all regulated qualifications, including the Higher Nationals in Engineering. This input should extend into the learning experience, where engagement with employers will add value to students, particularly in transferring theory into practice.

Centres should consider a range of employer engagement activities. These could include:

- field trips to local engineering facilities;
- inviting members of the local engineering community to present guest lectures;
- using practising engineers to judge the quality of assessed presentations;
- involving students in public events such as the Shell Mileage Marathon.

While detailed guidance on assessment has been provided in this specification (*see section 6*), it is worth considering the involvement of employers when determining assessment strategies and the use of different assessment methods. This would enable centres to design assessments that are more closely related to what students would be doing in the workplace. Employers would be able to comment on relevance and content, as well as the challenge presented by an assessment. Notwithstanding this, ultimately it is the centre's responsibility to judge the extent to which any employer contributes to teaching and learning.

5.3 Engaging with students

Students are integral to teaching and learning. As such, it is important they are involved as much as possible with most aspects of the programme onto which they are enrolled. This input could include taking into account their views on how teaching and learning will take place, their role in helping to design a curriculum, or on the assessment strategy that will test their knowledge and understanding.

There are many ways in which to capture the student voice and student feedback, both formal and informal. Formal mechanisms include the nomination of student representatives to act as the collective student voice for each student cohort, student representation at course team meetings and an elected higher education representative as part of the Student Union. Student forums should also take place periodically throughout the year with minutes and action plans updated and informing the overall annual course monitoring process. Unit-specific feedback can also be collated by students completing unit feedback forms, end-of-year course evaluations and scheduled performance review meetings with their tutor.

However, this should not be the only time when feedback from students is sought. Discourse with students should be constant, whereby tutors adopt a 'reflection on action' approach to adjust teaching, so that students are presented with an environment that is most supportive of their learning styles. Just as employers could have an input into assessment design, so too could students. This will support the development of assignments that are exciting and dynamic, and fully engage students in meaningful and informative assessment.

The biggest advantage of consulting students on their teaching, learning and assessment is securing their engagement in their own learning. Students are likely to feel empowered and develop a sense of ownership of all matters related to teaching, learning and assessment, not just their own experiences. Students could also view themselves as more accountable to their lecturers, ideally seeing themselves as partners in their own learning and not just part of a process.

5.4 Planning and structuring a programme

Learning should be challenging yet exciting; teaching should be motivating and inspirational. Consequently, both teaching and learning should form part of a programme structure that is active, flexible and progressive, and has an industry focus wherever possible.

It is important for a programme structure to be effectively planned, taking into account the nature of the student cohort, the primary mode of delivery (face-to-face or distance learning) and the level of study. It is also advisable to consider the student voice (whether that voice is heard through end-of-programme feedback or through ongoing dialogue) when planning how and when students will be exposed to a particular subject. One other vital source of information that centres would do well to embrace is the feedback from tutors who have been and/or will be delivering learning.

It is recommended that centres establish a programme planning forum where various stakeholders are represented. This forum could consider different perspectives of teaching and learning and how these are planned into an effective programme structure. Consideration could be given to, for example, the holistic and consistent use of virtual learning environments, a programme of field trips, a strategy for engaging with employers, and how and when to assess learning.

Consideration should be given to a number of factors when planning a programme structure. These include:

- the sequencing of units;
- whether to have condensed or expanded delivery;
- teaching and learning techniques.

5.4.1 Sequencing units

The level of demand embedded within a unit is benchmarked to recognised standards. This applies to all units within a level of study, and this means that all Level 4 units have similar demands, as do all Level 5 units. However, this does not mean that units can, or should, be delivered in any order. It is strongly advised that Level 4 units are delivered, and achieved, by students before progression to Level 5. However, students are able to progress to Level 5 with a minimum of 90 credits at Level 4.

Within each level it is advisable to sequence units so that those providing fundamental knowledge and understanding are scheduled early in the programme. It may also be advisable to schedule the assessment of units requiring the practice and application of more advanced skills later in the programme.

For example, at Level 4, Units 1 Engineering Design, 2 Engineering Mathematics and 3 Engineering Science could be the first three units that Higher National Certificate students study.

5.4.2 Condensed or expanded delivery

The next consideration is whether to deliver a unit in a condensed format alongside other units, or to deliver units over an expanded period. The following tables provide examples of this, based on four units being delivered in one teaching block.

Condensed version:

<table>
<tr><th>Weeks 1 to 6</th><th>Week 7</th><th>Weeks 8 to 13</th><th>Week 14</th></tr>
<tr><td>Unit 1</td><td rowspan="2">Assessment</td><td>Unit 3</td><td rowspan="2">Assessment</td></tr>
<tr><td>Unit 2</td><td>Unit 4</td></tr>
</table>

Expanded version:

<table>
<tr><th>Weeks 1 to 12</th><th>Weeks 13 and 14</th></tr>
<tr><td>Unit 1</td><td rowspan="4">Assessment</td></tr>
<tr><td>Unit 2</td></tr>
<tr><td>Unit 3</td></tr>
<tr><td>Unit 4</td></tr>
</table>

Mixed version:

<table>
<tr><th>Week 1</th><th>Week 2</th><th>Week 3</th><th>Week 4</th><th>Week 5</th><th>Week 6</th><th>Week 7</th><th>Week 8</th><th>Week 9</th><th>Week 10</th><th>Week 11</th><th>Week 12</th><th>Week 13</th><th>Week 14</th></tr>
<tr><td colspan="13">Unit 1</td><td rowspan="3">Assessment</td></tr>
<tr><td colspan="6">Unit 2</td><td>Assessment</td><td colspan="6">Unit 3</td></tr>
<tr><td colspan="13">Unit 4</td></tr>
</table>

The decision to deliver a condensed, expanded or mixed programme would depend on a number of factors, including availability of resources, the subjects to be taught and the requirements of students. Each version has advantages: the condensed version would provide an opportunity for students to gain early success and achievement. This will enhance their self-efficacy, the sense of one's belief in one's ability to succeed, and self-confidence, with tutors being able to identify and respond to less able students early in the teaching and learning cycle. The advantages of the expanded version include providing a longer timescale for students to absorb new knowledge and therefore, potentially, improve success, and giving tutors an opportunity to coach and support less able students over a longer period of time.

The mixed version, with some units spanning over the entire period and others lasting for shorter periods, provides opportunities for learning in some units to support development in others. This format may be particularly suited to a combination of practical and theoretical units. In all cases, the choice of which type of unit sequence must consider student opportunities as well as staff and physical resources of the centre.

As there are pros and cons to both approaches, the use of a planning forum would help to ensure the most appropriate approach is taken. For example, centres could choose to deliver the first teaching block using the expanded version, with the subsequent teaching block being delivered through a condensed approach.

It should be noted that the above consideration would apply equally to programmes that are being delivered face-to-face or through distance learning.

5.4.3 Drawing on a wide range of delivery techniques

As part of planning the range of delivery techniques that will be used to deliver the syllabus, centres should also consider an appropriate combination of techniques for the subject.

The table below lists, with explanation, some techniques that centres could introduce into a planned programme structure.

Technique	Face-to-face	Distance learning
Lecture and seminars	These are the most common techniques used by tutors. They offer an opportunity to engage with a large number of students, where the focus is on sharing knowledge through the use of presentations.	Delivery would be through video conferencing and/or pre-recorded audio and/or visual material, available through an online platform. Synchronous discussion forums could also be used.
Practical demonstrations	Demonstration by a qualified operator of the appropriate and safe operation of both production and testing equipment.	Delivery would normally occur when the students are physically present when the demonstration takes place, to allow interaction and questioning. In exceptional cases pre-recorded video material may be used.
Workshops	These are used to build on knowledge shared via tutors and seminars. Teaching can be more in-depth where knowledge is applied, for example to case studies or real-life examples. Workshops could be student-led, where students present, for example, findings from independent study.	While more challenging to organise than face-to-face delivery, workshops should not be dismissed. Smaller groups of three or four students could access a forum simultaneously and engage in the same type of activity as for face-to-face.

Technique	Face-to-face	Distance learning
Tutorials	These present an opportunity for focused one-to-one support, where teaching is led by an individual student's requirements. These can be most effective in the run up to assessment, where tutors can provide more focused direction, perhaps based on a formative assessment.	Other than not necessarily being in the same room as a student, tutors could still provide effective tutorials. Video conferencing tools such as Google+ or Skype provide the means to see a student, which makes any conversation more personal.
Virtual learning environments (VLEs)	These are invaluable to students studying on a face-to-face programme. Used effectively, VLEs not only provide a repository for taught material such as presentation slides or handouts, but could be used to set formative tasks such as quizzes. Further reading could also be located on a VLE, along with a copy of the programme documents, such as the handbook and assessment timetable.	Where students are engaged with online delivery through distance or blended learning a VLE is a must, as this would be the primary or key source of learning. Where distance learning is primarily delivered through hard copies of workbooks, etc., the same principle would apply as for face-to-face learning.
Blended learning	The combination of traditional face-to-face learning and online learning. This can enable the students to gain personalised support, instruction and guidance while completing assigned activities and tasks remotely.	Offline learning enables students to develop autonomy and self-discipline by completing set activities and tasks with limited direction and traditional classroom-based constraints.
Work-based learning	Any opportunity to integrate work-based learning into a curriculum should be taken. This adds realism and provides students with an opportunity to link theory to practice in a way in which case studies do not. Many full-time students are involved in some form of employment, either paid or voluntary, which could be used, where appropriate, as part of their learning e.g. when assignments require students to contextualise a response to a real organisation.	It is likely that the majority of distance learning students would be employed and possibly classed as mature students. Bringing theory to life through a curriculum, which requires work-based application of knowledge, would make learning for these students more relevant and meaningful. Perhaps more importantly, assessment should be grounded in a student's place of work, wherever possible.

Technique	Face-to-face	Distance learning
Guest speakers	These could be experts from industry or visiting academics in the subject area that is being studied. They could be used to present a lecture/seminar, a workshop or to contribute to assessment. The key message here would be to make the most effective use of an expert's knowledge and skill by adding value to the teaching and learning experience.	As long as the expert has access to the same platform as the students then the value-added contribution would still be very high. Consideration would need to be given to timings and logistics, but with some innovative management this technique would still have a place in distance learning programmes.
Field trips	Effectively planned field trips, which have a direct relevance to the syllabus, will add value to the learning experience. Through these trips students can relate theory to practice, have an opportunity to experience organisations in action, and potentially open their minds to career routes.	The use of field trips can be included as part of a distance learning programme. They will add the same value and require the same planning. One additional benefit of field trips for distance learning is that they provide an opportunity for all students in a cohort to meet, which is a rare occurrence for distance learning students.

5.4.4 Assessment considerations

Centres should embrace the concept of assessment for learning. This is where an assessment strategy requires students to engage with a variety of assessment tools that are accessible, appropriately challenging and support the development of student self-efficacy and self-confidence. To ensure that assignments are valid and reliable, centres must implement robust quality assurance measures and monitor the effectiveness of their implementation (see section 6 of this Programme Specification). This includes ensuring that all students engage in assessment positively and honestly.

Assessment also provides a learning opportunity for all stakeholders of the assessment to have access to feedback that is both individual to each student and holistic to the cohort. Feedback to students should be supportive and constructive. Student self-efficacy (and therefore self-confidence) can be significantly enhanced where feedback not only focuses on areas for improvement but recognises the strengths a student has. At the cohort level, similar trends could be identified that could inform future approaches to assessments and teaching. Assessment is an integral part of the overall learning process and assessment strategy must be developed to support effective, reflective, thinking engineering practitioners for the future. Assessment can be formative, summative or both.

5.4.5 Formative assessment

Formative assessment is primarily developmental in nature and designed to give feedback to students on their performance and progress. Assessment designed formatively should develop and consolidate knowledge, understanding, skills and competencies. It is a key part of the learning process and can enhance learning and contribute to raising standards.

Through formative assessment tutors can identify students' differing learning needs early on in the programme and so make timely corrective interventions. Tutors can also reflect on the results of formative assessment to measure how effective the planned teaching and learning is at delivering the syllabus. Each student should receive one set of written formative feedback, otherwise some students may feel that others are being given more than their share of verbal feedback.

5.4.6 Summative assessment

Summative assessment is where students are provided with the grades contributing towards the overall unit grade. For summative assessment to be effective it should also give students additional formative feedback to support ongoing development and improvement in subsequent assessments. All formative assessment feeds directly into summative assessment for each unit and lays the foundations from which students develop the necessary knowledge and skills required for the summative assessment.

5.4.7 Assessment feedback

Effective assessment feedback is part of continuous guided learning which promotes learning and enables improvement. It also allows students to reflect on their performance and helps them understand how to make effective use of feedback. Constructive and useful feedback should enable students to understand the strengths and limitations of their performance, providing positive comments where possible as well as explicit comments on how improvements can be made. Feedback should reflect the learning outcomes and marking criteria to further help students understand how these inform the process of judging the overall grade.

The timing of the provision of feedback and of the returned assessed work also contributes to making feedback effective. Specific turnaround time for feedback should be agreed and communicated with both tutors and students. Timing should provide time for students to reflect on the feedback and consider how to make use of it in forthcoming assessments and take into account the tutor's workload and ability to provide effective feedback.

5.4.8 Designing valid and reliable assessments

To help ensure valid and reliable assignments are designed and they are consistent across all units, centres could consider a number of actions.

Use of language

The first aspect of an assignment that a centre could focus on is language that makes tasks/questions more accessible to students.

Due consideration must be given to the command verbs used in the learning outcomes of a unit. Assignments must use appropriate command verbs that equate to the demand of the learning outcome. If the outcome requires analysis then evaluative tasks/questions within the assignment must not be set when testing that outcome. This would be viewed as over-assessing. Similarly it is possible to under-assess where analytical demands are tested using, for example, explanatory command verbs.

The following can be used as a guide to support assignment design:

- Ensure there is a holistic understanding (by tutors and students) and use of command verbs.
- Set assignment briefs that use a single command verb, focusing on the highest level of demand expected for the learning outcome(s) being tested.
- Assignments should be supported by additional guidance that helps students to interpret the demand of the question or task.
- Time-constrained assessments should use the full range of command verbs (or acceptable equivalents) appropriate to the academic level.

Consistency

This relates to consistency of presentation and structure, consistent use of appropriate assessment language, and the consistent application of grading criteria. Where assignments are consistent, reliability is enhanced. Where validity is present in assignments this will result in assignments that are fit for purpose and provide a fair and equitable opportunity for all students to engage with the assignment requirements.

Employing a range of assessment tools

Just as variety of teaching is important to the planning of a programme structure, so too is the use of a range of assessment tools appropriate to the unit and its content. Centres should consider taking a holistic view of assessment, ensuring a balanced assessment approach with consideration given to the subject being tested and what is in the best interests of students. As mentioned above, consultation with employers could add a sense of realism to an assessment strategy. (A comprehensive list of assessment tools is provided in section 6.2 Setting effective assessments.)

Some of the assessment tools that could be used are:

- work-based projects;
- written assignments:
  - reports
  - briefing documents
  - planning documents
  - design documents
  - machine operating instructions in the form of a computer program
  - solutions to engineering problems through discourse and/or calculation;
- presentations, vivas, role plays supported by an observer's statement and/or video evidence;
- portfolios;

- reflective statements;
- production of artefacts;
- work log books;
- witness statements.

No matter what tool is used, assignments should have a sector focus, whether this is in a workplace context or through a case study, and be explicitly clear in their instructions. In the absence of a case study a scenario should be used to provide some context. Finally, students should be clear on the purpose of the assignment and which elements of the unit it is targeting.

6. Assessment

BTEC Higher Nationals in Engineering are assessed using a combination of internally assessed centre-devised internal assignments (which are set and marked by centres) and internally assessed Pearson-set assignments (which are set by Pearson and marked by centres). Pearson-set assignments are mandatory and target particular industry-specific skills. The number and value of these units are dependent on qualification size:

- For the HNC, one core, 15 credit, unit at Level 4 will be assessed by a mandatory Pearson-set assignment targeted at particular skills;
- For the HND, two core units: one core, 15 credit, unit at Level 4 and one core, 30 credit, unit at Level 5, will be assessed by a mandatory Pearson-set assignment targeted at particular skills;
- all other units are assessed by centre-devised assignments.

The purpose and rationale of having Pearson-set units on Higher Nationals is as follows:

- **Standardisation of student work** – Assessing the quality of student work, that it is meeting the level and the requirements of the unit across all centres, that grade decisions and assessor feedback are justified, and that internal verification and moderation processes are picking up any discrepancies and issues.
- **Sharing of good practice** – We will share good practice in relation to themes such as innovative approaches to delivery, the use of digital literacy, enhancement of student employability skills and employer engagement. **These themes will align to those for QAA Higher Education Reviews**.

An appointed External Examiner (EE) for the centre will ask to sample the Pearson-set assignment briefs in advance of the external examination visit. Although this is not a mandatory requirement for centres, we strongly advise that centres seek guidance and support from their EE on the Pearson-set assignments. The EE may also include the Pearson-set units in their sample of student work during their centre visit.

We have taken great care to ensure that the assessment method chosen is appropriate to the content of the unit and in line with requirements from professional bodies, employers and higher education.

In developing an overall plan for delivery and assessment for the programme, you will need to consider the order in which you deliver units, whether delivery will take place over short or long periods of time, and when assessment can take place.

Example Assessment Briefs

Each unit has supporting Example Assessment Briefs that are available to download from the course materials section on our website (http://qualifications.pearson.com/). The Example Assessment Briefs are there to give you an example of what the assessment will look like in terms of the content and level of demand of the assessment.

The Example Assessment Briefs, with the exception of the mandatory Pearson-set unit, provide tutors with suggested types of assignment and structure, which can be adopted and, if so, **must be** adapted accordingly.

6.1 Principles of internal assessment

This section gives an overview of the key features of internal assessment and how you, as an approved centre, can offer it effectively. The full requirements and operational information are given in the Pearson Quality Assurance Handbook available in the support section of our website (http://qualifications.pearson.com/). All of the assessment team will need to refer to this document.

For BTEC Higher Nationals it is important that you can meet the expectations of stakeholders and the needs of students by providing a programme that is practical and applied. Centres can tailor programmes to meet local needs and should use links with local employers and the wider engineering sector.

When internal assessment is operated effectively it is challenging, engaging, practical and up to date. It must also be fair to all students and meet national standards.

Assessment through assignments

For internally assessed units the format of assessment is an assignment taken after the content of the unit, or part of the unit if several assignments are used, has been fully delivered. An assignment may take a variety of forms, including practical and written types. An assignment is a distinct activity completed independently by students (either alone or in a team). An assignment is separate from teaching, practice, exploration and other activities that students complete with direction from and formative assessment by tutors.

An assignment is issued to students as an **assignment brief** with an issue date, a completion date and clear requirements for the evidence that students are expected to provide. There may be specific observed practical components during the assignment period. Assignments can be divided into separate parts and may require several forms of evidence. A valid assignment will enable a clear and formal assessment outcome based on the assessment criteria.

Assessment decisions through applying unit-based criteria

Assessment decisions for BTEC Higher Nationals are based on the specific criteria given in each unit and set at each grade level. The criteria for each unit have been defined according to a framework to ensure that standards are consistent in the qualification and across the suite as a whole. The way in which individual units are written provides a balance of assessment of understanding, practical skills and vocational attributes appropriate to the purpose of the qualifications.

The assessment criteria for a unit are hierarchical and holistic. For example, if a Merit criterion requires the student to show 'analysis' and the related P criterion requires the student to 'explain', then to satisfy the Merit criterion a student will need to cover both 'explain' and 'analysis'. The unit assessment grid shows the relationships among the criteria so that assessors can apply all the criteria to the student's evidence at the same time. In *Appendix 5* we have set out a definition of terms that assessors need to understand.

Assessors must show how they have reached their decisions using the criteria in the assessment records. When a student has completed all the assessment for a unit then the assessment team will give a grade for the unit. This is given simply according to the highest level for which the student is judged to have met all the criteria. Therefore:

- to achieve a **Pass**, a student must have satisfied all the Pass criteria for the learning aims, showing coverage of the unit content and therefore attainment at Level 4 or 5 of the national framework;
- to achieve a **Merit**, a student must have satisfied all the Merit criteria (and therefore the Pass criteria) through high performance in each learning outcome;
- to achieve a **Distinction**, a student must have satisfied all the Distinction criteria (and therefore the Pass and Merit criteria); these define outstanding performance across the unit as a whole.

The award of a Pass is a defined level of performance and cannot be given solely on the basis of a student completing assignments. Students who do not satisfy the Pass criteria should be reported as Unclassified.

The assessment team

It is important that there is an effective team for internal assessment. There are three key roles involved in implementing assessment processes in your centre, each with different interrelated responsibilities, and these roles are listed below. Full information is given in the Pearson Quality Assurance Handbook available in the support section of our website (http://qualifications.pearson.com/).

- **The Programme Leader** has overall responsibility for the programme, its assessment and internal verification to meet our requirements, record keeping and liaison with the External Examiner. The Programme Leader registers with Pearson annually and acts as an assessor, supports the rest of the assessment team, makes sure they have the information they need about our assessment requirements, and organises training, making use of our guidance and support materials.
- **Internal Verifiers** (IVs) oversee all assessment activity in consultation with the Programme Leader. They check that assignments and assessment decisions are valid and that they meet our requirements. IVs will be standardised by working with the Programme Leader. Normally, IVs are also assessors, but they do not verify their own assessments.
- **Assessors** set or use assignments to assess students to national standards. Before taking any assessment decisions, assessors participate in standardisation activities led by the Programme Leader. They work with the Programme Leader and IVs to ensure that the assessment is planned and carried out in line with our requirements.
- Your **External Examiner** (EE) will sample student work across assessors. Your EE will also want to see evidence of internal verification of assignments and access decisions.

Effective organisation

Internal assessment needs to be well organised so student progress can be tracked and we can ensure that assessment is being carried out in line with national standards. We support you in this through, for example, providing training materials and sample documentation. Our online HN Global service can also help support you in planning and record keeping.

It is particularly important that you manage the overall assignment programme and deadlines to make sure that all your students are able to complete assignments on time.

Student preparation

To ensure that you provide effective assessment for your students, you need to make sure they understand their responsibilities for assessment and the centre's arrangements. From induction onwards you will want to ensure that students are motivated to work consistently and independently to achieve the requirements of the qualifications. They need to understand how assignments are used, the importance of meeting assignment deadlines and that all the work submitted for assessment must be their own.

You will need to give your students a guide that explains:

- how assignments are used for assessment;
- how assignments relate to the teaching programme;
- how students should use and reference source materials, including what would constitute plagiarism.

The guide should also set out your approach to operating assessment, such as how students must submit work, the consequences of submitting late work and the procedure for requesting extensions for mitigating circumstances.

6.2 Setting effective assignments

Setting the number and structure of assignments

In setting your assignments you need to work with the structure of assignments shown in the relevant section of a unit. This shows the learning aims and outcomes and the criteria you must follow.

Pearson provide Example Assessment Briefs for each unit to support you in developing and designing your own assessments. You can find these materials with the specification on our website.

In designing your own assignment briefs, you should bear in mind the following points:

- The number of assignments for a unit must not exceed the number of learning outcomes shown in the unit descriptor. However, you may choose to combine assignments, e.g. to create a single assignment for the whole unit.
- You may also choose to combine all or parts of different units into single assignments, provided that all units and all their associated learning aims are fully addressed in the programme overall. If you choose to take this approach you need to make sure that students are fully prepared, so they can provide all the required evidence for assessment, and you are able to track achievement in assessment records.
- A learning outcome must always be assessed as a whole and must not be split into two or more elements.
- The assignment must be targeted to the learning outcomes but the learning outcomes and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.

You do not have to follow the order of the learning outcomes of a unit in setting assignments, but later Learning Outcomes often require students to apply the content of earlier learning aims, and they may require students to draw their learning together.

Assignments must be structured to allow students to demonstrate the full range of achievement at all grade levels. Students need to be treated fairly by being given the opportunity to achieve a higher grade, if they have the ability.

As assignments provide a final assessment, they will draw on the specified range of teaching content for the learning outcomes. **The specified unit content must be taught/delivered**. The evidence for assessment need not cover every aspect of the teaching content, as students will normally be given particular examples, case studies or contexts in their assignments. For example, if a student is carrying out one practical operation, or an investigation of one organisation, then they will address all the relevant range of content that applies in that instance.

Providing an assignment brief

A good assignment brief is one that, through providing challenging and authentic sector/work-related tasks, motivates students to provide appropriate evidence of what they have learned.

An assignment brief should have:

- a vocational scenario: this could be a simple situation or a full, detailed set of vocational requirements that motivates the student to apply their learning through the assignment;
- clear instructions to the student about what they are required to do, normally set out through a series of tasks;
- an audience or purpose for which the evidence is being provided;
- an explanation of how the assignment relates to the unit(s) being assessed.

Forms of evidence

BTEC Higher Nationals have always allowed for a variety of forms of assessment evidence to be used, provided they are suited to the type of learning aim being assessed. For many units, the practical demonstration of skills is necessary and, for others, students will need to carry out their own research and analysis, working independently or as part of a team.

The Example Assessment Briefs give you information on what would be suitable forms of evidence to give students the opportunity to apply a range of employability or transferable skills. Centres may choose to use different suitable forms of evidence to those proposed. Overall, students should be assessed using varied forms of evidence.

These are some of the main types of assessment:

- written reports
- time-constrained assessments
- creation of design documents
- projects
- production of an artefact
- solutions to engineering problems through discourse and/or calculation

- academic posters, displays, leaflets
- PowerPoint (or similar) presentations
- recordings of interviews/role plays
- working logbooks, reflective journals
- presentations with assessor questioning.

(Full definitions of types of assessment are given in *Appendix 5*.)

The form(s) of evidence selected must:

- allow the student to provide all the evidence required for the learning aim(s) and the associated assessment criteria at all grade levels;
- allow the student to produce evidence that is their own independent work;
- allow a verifier to independently reassess the student to check the assessor's decisions.

For example, when you are using performance evidence, you need to think about how supporting evidence can be captured through recordings, photographs or task sheets.

Centres need to take particular care that students are enabled to produce independent work. For example, if students are asked to use real examples, then best practice would be to encourage them to use examples of their own or to give the group a number of examples that can be used in varied combinations.

6.3 Making valid assessment decisions

Authenticity of student work

An assessor must assess only student work that is authentic, i.e. students' own independent work. Students must authenticate the evidence that they provide for assessment through signing a declaration stating that it is their own work. A student declaration must state that:

- Evidence submitted for that assignment is the student's own
- The student understands that false declaration is a form of malpractice.

Assessors must ensure that evidence is authentic to a student through setting valid assignments and supervising them during the assessment period. Assessors must also take care not to provide direct input, instructions or specific feedback that may compromise authenticity.

Centres may use Pearson templates or their own templates to document authentication.

During assessment an assessor may suspect that some or all of the evidence from a student is not authentic. The assessor must then take appropriate action using the centre's policies for malpractice. (See section 3.7 in this Programme Specification for further information.)

Making assessment decisions using criteria

Assessors make judgements using the criteria. The evidence from a student can be judged using all the relevant criteria at the same time. The assessor needs to make a judgement against each criterion that evidence is present and sufficiently comprehensive. For example, the inclusion of a concluding section may be insufficient to satisfy a criterion requiring 'evaluation'.

Assessors should use the following information and support in reaching assessment decisions:

- the explanation of key terms in Appendix 4 of this document
- examples of moderated assessed work
- Your Programme Leader and assessment team's collective experience.

Dealing with late completion of assignments

Students must have a clear understanding of the centre's policy on completing assignments by the deadlines that you give them. Students may be given authorised extensions for legitimate reasons, such as illness, at the time of submission, in line with your centre policies (see also Section 3.6 "Administrative arrangements for internal assessment").

For assessment to be fair, it is important that students are all assessed in the same way and that some students are not advantaged by having additional time or the opportunity to learn from others. Centres should develop and publish their own regulations on late submission; and, this should make clear the relationship between late submission and the centre's mitigating circumstances policy.

Centres may apply a penalty to assignments that are submitted beyond the published deadline. However, if a late submission is accepted, then the assignment should be assessed normally, when it is submitted, using the relevant assessment criteria; with any penalty or cap applied after the assessment. Where the result of assessment may be capped, due to late submission of the assignment, the student should be given an indication of their uncapped mark; in order to recognise the learning that has been achieved, and assessment feedback should be provided in relation to the uncapped achievement.

As with all assessment results, both the uncapped and capped marks should be recorded and ratified by an appropriate assessment board; taking into account any mitigating circumstances that may have been submitted.

Issuing assessment decisions and feedback

Once the assessment team has completed the assessment process for an assignment, the outcome is a formal assessment decision. This is recorded and reported to students. The information given to the student:

- must show the formal decision and how it has been reached, indicating how or where criteria have been met;
- may show why attainment against criteria has not been demonstrated;
- must not provide feedback on how to improve evidence but how to improve in the future.

Resubmission opportunity

An assignment provides the final assessment for the relevant learning outcomes and is normally a final assessment decision. A student who, for the first assessment opportunity, has failed to achieve a Pass for that unit specification **shall be expected to undertake a reassessment**.

- Only one opportunity for reassessment of the unit will be permitted
- Reassessment for coursework, project or portfolio-based assessments shall normally involve the reworking of the original task
- For examinations, reassessment shall involve completion of a new task
- A student who undertakes a reassessment will have their grade capped at a Pass for that unit
- A student will not be entitled to be reassessed in any component of assessment for which a Pass grade or higher has already been awarded.

Repeat units

For a student who, for the first assessment opportunity and resubmission opportunity, still failed to achieve a Pass for that unit specification:

- At Centre discretion and Assessment Board, decisions can be made to permit a repeat of a unit.
- The student must study the unit again with full attendance and payment of the unit fee.
- The overall unit grade for a successfully completed repeat unit is capped at a Pass for that unit.
- Units can only be repeated once.

Assessment Boards

Each centre is expected by Pearson to hold Assessment Boards for all of its BTEC Higher National programmes. The main purpose of an Assessment Board is to make recommendations on:

- The grades achieved by students on the individual units
- Extenuating circumstances
- Cases of cheating and plagiarism
- Progression of students on to the next stage of the programme
- The awards to be made to students
- Referrals and deferrals.

Assessment Boards may also monitor academic standards. The main boards are normally held at the end of the session, although if your centre operates on a semester system there may be (intermediate) boards at the end of the first semester. There may also be separate boards to deal with referrals.

Where a centre does not currently have such a process then the External Examiner (EE) should discuss this with the Quality Nominee and Programme Leader, stressing the requirement for Assessment Boards by both Pearson and QAA and that Assessment Board reports and minutes provide valuable evidence for QAA's Review of College Higher Education process.

6.4 Planning and record keeping

For internal processes to be effective, an assessment team needs to be well organised and keep effective records. The centre will also work closely with us so that we can quality assure that national standards are being satisfied. This process gives stakeholders confidence in the assessment approach.

The Programme Leader must have an assessment plan, produced as a spreadsheet. When producing a plan the assessment team will wish to consider:

- the time required for training and standardisation of the assessment team;
- the time available to undertake teaching and carrying out of assessment, taking account of when students may complete external assessments and when quality assurance will take place;
- the completion dates for different assignments;
- who is acting as Internal Verifier (IV) for each assignment and the date by which the assignment needs to be verified;
- setting an approach to sampling assessor decisions though internal verification that covers all assignments, assessors and a range of students;
- how to manage the assessment and verification of students' work so that they can be given formal decisions promptly;
- how resubmission opportunities can be scheduled.

The Programme Leader will also maintain records of assessment undertaken. The key records are:

- verification of assignment briefs
- student authentication declarations
- assessor decisions on assignments, with feedback given to students
- verification of assessment decisions.

Examples of records and further information are available in the Pearson Quality Assurance Handbook available in the support section of our website (http://qualifications.pearson.com).

6.5 Calculation of the final qualification grade

Conditions for the Award

Conditions for the Award of the HND

To achieve a Pearson BTEC Higher National Diploma qualification a student must have:

- completed units equivalent to 120 credits at level 5;
- achieved at least a pass in 105 credits at level 5;
- completed units equivalent to 120 credits at level 4;
- achieved at least a pass in 105 credits at level 4.

Conditions for the award of the HNC

To achieve a Pearson BTEC Higher National Certificate qualification a student must have:

- completed units equivalent to 120 credits at level 4;
- achieved at least a pass in 105 credits at level 4.

Compensation Provisions

Compensation Provisions for the HND

Students can still be awarded an HND if they have attempted but not achieved a Pass in one of the 15 credit units completed at level 4 and similarly if they have attempted but not achieved a Pass in one of the 15 credit units at level 5. However they must complete and pass the remaining units for an HNC or HND as per the unit rules of combination of the required qualification.

Compensation Provisions for the HNC

Students can still be awarded an HNC if they have not achieved a Pass in one of the 15 credit units completed, but have completed and passed the remaining units.

Calculation of the overall qualification grade

The calculation of the overall qualification grade is based on the student's performance in all units. Students are awarded a Pass, Merit or Distinction qualification grade using the points gained through all 120 credits, at Level 4 for the HNC or Level 5 for the HND, based on unit achievement. The overall qualification grade is calculated in the same way for the HNC and for the HND.

All units in valid combination must have been attempted for each qualification. The conditions of award and the compensation provisions will apply as outlined above. All 120 credits count in calculating the grade (at each level, as applicable).

The overall qualification grade for the HND will be calculated based on student performance in Level 5 units only.

Units that have been attempted but not achieved, and subsequently granted compensation, will appear as 'Unclassified'; i.e. a 'U' grade, on the student's Notification of Performance, that is issued with the student certificate.

Points per credit

Pass: 4

Merit: 6

Distinction: 8

Point boundaries

Grade	Point boundaries
Pass	420−599
Merit	600−839
Distinction	840 +

Modelled Student Outcomes

Level 4 Higher National Certificate

	STUDENT 1					STUDENT 2		STUDENT 3		STUDENT 4		STUDENT 5	
	Credits	Level	Grade	Grade point	Unit points	Grade	Unit points	Grade	Unit points	Grade	Unit points	Grade	Unit points
Core 1	15	4	P	4	60	P	60	P	60	D	120	D	120
Core 2	15	4	P	4	60	P	60	P	60	D	120	M	90
Core 3	15	4	P	4	60	P	60	P	60	D	120	M	90
Core 4	15	4	P	4	60	P	60	M	90	M	90	M	90
Core 5	15	4	M	6	90	P	60	M	90	M	90	M	90
Core 6	15	4	M	6	90	P	60	M	90	M	90	M	90
Opt 1	15	4	M	6	90	M	90	D	120	D	120	D	120
Opt 2	15	4	M	6	90	M	90	D	120	D	120	D	120
TOTAL					600		540		690		870		810
GRADE					M		P		M		D		M

Level 5 Higher National Diploma

	STUDENT 1					STUDENT 2		STUDENT 3		STUDENT 4		STUDENT 5	
	Credits	Level	Grade	Grade point	Unit points	Grade	Unit points	Grade	Unit points	Grade	Unit points	Grade	Unit points
Core 1	15	4	P	0	0	P	0	P	0	D	0	P	0
Core 2	15	4	P	0	0	P	0	P	0	D	0	M	0
Core 3	15	4	P	0	0	P	0	P	0	D	0	M	0
Core 4	15	4	P	0	0	P	0	M	0	M	0	M	0
Core 5	15	4	M	0	0	P	0	M	0	M	0	P	0
Core 6	15	4	M	0	0	P	0	M	0	D	0	U	0
Opt 1	15	4	M	0	0	P	0	D	0	D	0	D	0
Opt 2	15	4	M	0	0	P	0	D	0	D	0	D	0
Core 7	30	5	M	6	180	M	180	M	180	P	120	D	240
Core 8	15	5	M	6	90	M	90	M	90	P	60	D	120
Opt 3	15	5	M	6	90	M	90	D	120	P	60	D	120
Opt 4	15	5	M	6	90	P	60	D	120	P	60	D	120
Opt 5	15	5	M	6	90	P	60	D	120	M	90	M	90
Opt 6	15	5	M	6	90	P	60	M	90	M	90	P	60
Opt 7	15	5	M	6	90	P	60	M	90	M	90	M	90
TOTAL	240				720		600		810		570		840
GRADE					M		M		M		P		D

7. Quality assurance

Pearson's quality assurance system for all Pearson BTEC Higher National programmes is benchmarked to Level 4 and Level 5 on the Quality Assurance Agency (QAA) Framework for Higher Education Qualifications (FHEQ). This will ensure that centres have effective quality assurance processes to review programme delivery. It will also ensure that the outcomes of assessment are to national standards.

The quality assurance process for centres offering Pearson BTEC Higher National programmes comprises five key components:

1. The approval process
2. Monitoring of internal centre systems
3. Independent assessment review
4. Annual programme monitoring report
5. Annual student survey.

7.1 The approval process

Centres new to the delivery of Pearson programmes will be required to seek approval initially through the existing centre approval process and then through the programme approval process. Programme approval for new centres can be considered in one of two ways:

- Desk-based approval review
- Review and approval visit to the centre.

Prior to approval being given, centres will be required to submit evidence to demonstrate that they:

- have the human and physical resources required for effective delivery and assessment;
- understand the implications for independent assessment and agree to abide by these;
- have a robust internal assessment system supported by 'fit-for-purpose' assessment documentation;
- have a system to internally verify assessment decisions, to ensure standardised assessment decisions are made across all assessors and sites.

Applications for approval must be supported by the head of the centre (Principal or Chief Executive, etc.) and include a declaration that the centre will operate the programmes strictly, as approved and in line with Pearson requirements.

Centres seeking to renew their programme approval upon expiry of their current approval period may be eligible for the Automatic Approval process, subject to the centre meeting the eligibility criteria set out by Pearson.

Regardless of the type of centre, Pearson reserves the right to withdraw either qualification or centre approval when it deems there is an irreversible breakdown in the centre's ability to quality assure either its programme delivery or assessment standards.

7.2 Monitoring of internal centre systems

Centres will be required to demonstrate ongoing fulfilment of the centre approval criteria over time and across all Higher National programmes. The process that assures this is external examination, which is undertaken by External Examiners. Centres will be given the opportunity to present evidence of the ongoing suitability and deployment of their systems to carry out the required functions. This includes the consistent application of policies affecting student registrations, appeals, effective internal examination and standardisation processes. Where appropriate, centres may present evidence of their operation within a recognised code of practice, such as that of the Quality Assurance Agency for Higher Education. Pearson reserves the right to confirm independently that these arrangements are operating to Pearson's standards.

Pearson will affirm, or not, the ongoing effectiveness of such systems. Where system failures are identified, sanctions (appropriate to the nature of the problem) will be applied to assist the centre in correcting the problem.

7.3 Independent assessment review

The internal assessment outcomes reached for all Pearson BTEC Higher National programmes benchmarked to Level 4 and Level 5 of QAA's Framework for Higher Education Qualifications (FHEQ) are subject to an independent assessment review by a Pearson appointed External Examiner. The outcomes of this process will be:

- to confirm that internal assessment is to national standards and allow certification, OR
- to make recommendations to improve the quality of assessment outcomes before certification is released, OR
- to make recommendations about the centre's ability to continue to be approved for the Pearson BTEC Higher National qualifications in question.

7.4 Annual programme monitoring report (APMR)

The APMR is a written annual review form that provides an opportunity for centres to analyse and reflect on the most recent teaching year. By working in collaboration with centres, the information can be used by Pearson to further enhance the quality assurance of the Pearson BTEC Higher National programmes.

7.5 Annual student survey

Pearson will conduct an annual survey of Pearson BTEC Higher National students. The purpose of the survey is to enable Pearson to evaluate the student experience as part of the quality assurance process, by engaging with students studying on these programmes.

7.6 Centre and qualification approval

As part of the approval process, your centre must make sure that the resource requirements listed below are in place before offering the qualification.

Centres must have appropriate physical resources (for example, equipment, IT, learning materials, teaching rooms) to support the delivery and assessment of the qualifications.

- Staff involved in the assessment process must have relevant expertise and/or occupational experience.
- Systems must be in place to ensure continuing professional development for staff delivering the qualification.
- Centres must have in place appropriate health and safety policies relating to the use of equipment by staff and students.
- Centres must deliver the qualification in accordance with current equality legislation.
- Centres should refer to the individual unit descriptors to check for any specific resources required.

The result, we believe, are qualifications that will meet the needs and expectations of students worldwide.

7.7 Continuing quality assurance and standards verification

We produce annually the latest version of the Pearson Quality Assurance Handbook available in the support section of our website (http://qualifications.pearson.com). It contains detailed guidance on the quality processes required to underpin robust assessment and internal verification.

The key principles of quality assurance are that:

- A centre delivering Pearson BTEC Higher National programmes must be an approved centre, and must have approval for the programmes or groups of programmes that it is delivering.
- The centre agrees, as part of gaining approval, to abide by specific terms and conditions around the effective delivery and quality assurance of assessment; it must abide by these conditions throughout the period of delivery.
- Pearson makes available to approved centres a range of materials and opportunities, through the assessment checking service. This is intended to exemplify the processes required for effective assessment and provide examples of effective standards. Approved centres must use the materials and services to ensure that all staff delivering BTEC qualifications keep up to date with the guidance on assessment.
- An approved centre must follow agreed protocols for standardisation of assessors and verifiers, for the planning, monitoring and recording of assessment processes, and for dealing with special circumstances, appeals and malpractice.

The approach of quality-assured assessment is through a partnership between an approved centre and Pearson. We will make sure that each centre follows best practice and employs appropriate technology to support quality assurance processes, where practicable. We work to support centres and seek to make sure that our quality assurance processes do not place undue bureaucratic processes on centres. We monitor and support centres in the effective operation of assessment and quality assurance.

The methods we use to do this for BTEC Higher Nationals include:

- making sure that all centres complete appropriate declarations at the time of approval;
- undertaking approval visits to centres;
- making sure that centres have effective teams of assessors and verifiers who are trained to undertake assessment;
- assessment sampling and verification, through requested samples of assessments, completed assessed student work and associated documentation;
- an overarching review and assessment of a centre's strategy for assessing and quality assuring its BTEC programmes.

An approved centre must make certification claims only when authorised by us and strictly in accordance with requirements for reporting. Centres that do not fully address and maintain rigorous approaches to quality assurance cannot seek certification for individual programmes or for all BTEC Higher National qualifications.

Centres that do not comply with remedial action plans may have their approval to deliver qualifications removed.

8. Recognition of Prior Learning and attainment

Recognition of Prior Learning (RPL) is a method of assessment (leading to the award of credit) that considers whether students can demonstrate that they can meet the assessment requirements for a unit through knowledge, understanding or skills they already possess, and so do not need to develop through a course of learning.

Pearson encourages centres to recognise students' previous achievements and experiences whether at work, home and at leisure, as well as in the classroom. RPL provides a route for the recognition of the achievements resulting from continuous learning. RPL enables recognition of achievement from a range of activities using any valid assessment methodology. Provided that the assessment requirements of a given unit or qualification have been met, the use of RPL is acceptable for accrediting a unit, units or a whole qualification. Evidence of learning must be valid and reliable.

For full guidance on RPL please refer to the Recognition of Prior Learning policy document available in the support section of our website (https://qualifications.pearson.com).

9. Equality and diversity

Equality and fairness are central to our work. The design of these qualifications embeds consideration of equality and diversity as set out in the Quality Assurance Agency's Quality Code and Ofqual's General Conditions of Recognition. Promoting equality and diversity involves treating everyone with equal dignity and worth, while also raising aspirations and supporting achievement for people with diverse requirements, entitlements and backgrounds. An inclusive environment for learning anticipates the varied requirements of students, and aims to ensure that all students have equal access to educational opportunities. Equality of opportunity involves enabling access for people who have differing individual requirements as well as eliminating arbitrary and unnecessary barriers to learning. In addition, students with and without disabilities are offered learning opportunities that are equally accessible to them, by means of inclusive qualification design.

Pearson's equality policy requires all students to have equal opportunity to access our qualifications and assessments. It also requires our qualifications to be designed and awarded in a way that is fair to every student. We are committed to making sure that:

- Students with a protected characteristic (as defined in legislation) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic.
- all students achieve the recognition they deserve from undertaking a qualification and this achievement can be compared fairly to the achievement of their peers.

Pearson's policy regarding access to its qualifications is that:

- they should be available to everyone who is capable of reaching the required standards;
- they should be free from any barriers that restrict access and progression;
- there should be equal opportunities for all wishing to access the qualifications.

Centres are required to recruit students to Higher National qualifications with integrity. This will include ensuring that applicants have appropriate information and advice about the qualifications, and that the qualification will meet their needs. Centres will need to review the entry profile of qualifications and/or experience held by applicants, considering whether this profile shows an ability to progress to a higher-level qualification. Centres should take appropriate steps to assess each applicant's potential and make a professional judgement about their ability to successfully complete the programme of study and achieve the qualification. This assessment will need to take account of the support available to the student within the centre during their programme of study and any specific support that might be necessary to allow the student to access the assessment for the qualification. Centres should consult our policy on students with particular requirements.

Access to qualifications for students with disabilities or specific needs

Students taking a qualification may be assessed in a recognised regional sign language, where it is permitted for the purpose of reasonable adjustments. Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document Access Arrangements, Reasonable Adjustments and Special Consideration for General and Vocational qualifications. Details on how to make adjustments for students with protected characteristics are given in the document *Pearson Supplementary Guidance for Reasonable Adjustments* and *Special Consideration in Vocational Internally Assessed Units*. See the support section our website for both documents (http://qualifications.pearson.com/).

10. Higher Nationals Nuclear Engineering Units

Unit 1: Engineering Design

Unit code K/615/1475

Unit type Core

Unit level 4

Credit value 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; 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, modelling and prototyping, manufacturability, reliability life cycle, safety and risk, management, calculations, drawings and concepts and ergonomics.

On successful completion of this unit students will be able to prepare an engineering design specification that satisfies stakeholders' requirements, implement best practice 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:

1. Plan a design solution and prepare an engineering design specification in response to a stakeholder’s design brief and requirements.
2. Formulate possible technical solutions to address the student-prepared design specification.
3. Prepare an industry-standard engineering technical design report.
4. Present to an audience a design solution based on the design report and evaluate the solution/presentation.

Essential Content

LO1 **Plan a design solution and prepare an engineering design specification in response to a stakeholder's design brief and requirements**

Planning techniques used to prepare a design specification:

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

Definition of design constraints, function, specification, milestones

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

Use of relevant technical/engineering/industry standards within the design process

Design process:

Process development, steps to consider from start to finish

The cycle from design to manufacture

Three- and five-stage design process

Vocabulary used in engineering design

Stage of the design process which includes:

Analysing the situation, problem statement, define tasks and outputs, create the design concept, research the problem and write a specification

Suggest possible solutions, select a preferred solution, prepare working drawings, construct a prototype, test and evaluate the design against objectives, design communication (write a report)

Customer/stakeholder requirements:

Converting customer request 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 **Formulate possible technical solutions to address the student-prepared design specification**

Conceptual design and evaluating possible solutions:

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

Use of evaluation and analytical tools, e.g. cause and effect diagrams, CAD, knowledge-based engineering

LO3 **Prepare an industry-standard engineering technical design report**

Managing the design process:

Recognising limitations including cost, physical processes, availability of material/components and skills, timing and scheduling

Working to specifications and standards, including:

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

Design for testing, including:

Material selection to suit selected processes and technologies

Consideration of manufacturability, reliability, life cycle and environmental issues

The importance of safety, risk management and ergonomics

Conceptual design and effective tools:

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

LO4 **Present to an audience a design solution based on the design report and evaluate the solution/presentation**

Communication and post-presentation review:

Selection of presentation tools

Analysis of presentation feedback

Strategies for improvement based on feedback

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Plan a design solution and prepare an engineering design specification in response to a stakeholder’s design brief and requirements</td><td rowspan="2">D1 Compare and contrast the completed design specification against the relevant industry standard specification</td></tr>
<tr><td>P1 Produce 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</td><td>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 its use</td></tr>
<tr><td colspan="2">LO2 Formulate possible technical solutions to address the student-prepared design specification</td><td rowspan="2">D2 Evaluate potential technical solutions, presenting a case for the final choice of solution</td></tr>
<tr><td>P4 Explore industry standard evaluation and analytical tools in formulating possible technical solutions

P5 Use appropriate design techniques to produce a possible design solution</td><td>M3 Apply the principles of modelling, simulation and/or prototyping, using appropriate software, to develop an appropriate design solution</td></tr>
</table>

Pass	Merit	Distinction
LO3 Prepare an industry-standard engineering technical design report		**D3** Evaluate the effectiveness of the industry standard engineering technical design report for producing a fully compliant finished product
P6 Prepare an industry-standard engineering technical design report **P7** Explain the role of design specifications and standards in the technical design report	**M4** Assess any compliance, safety and risk management issues specific to the technical design report	
LO4 Present to an audience a design solution based on the design report and evaluate the solution/presentation		**D4** Justify potential improvements to the design solution and/or presentation based on reflection and/or feedback
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	

Recommended Resources

Textbooks

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.

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

Websites

www.epsrc.ac.uk	Engineering and Physical Sciences Research Council (General Reference)
www.imeche.org	Institution of Mechanical Engineers (General Reference)

Links

This unit links to the following related units:

Unit 23: Computer Aided Design and Manufacture (CAD/CAM)

Unit 34: Research Project

Unit 2: Engineering Maths

Unit code	**M/615/1476**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

The mathematics that is delivered in this unit is that which is directly applicable to the engineering 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 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 problems.

Learning Outcomes

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

1. Identify the relevance of mathematical methods to a variety of conceptualised engineering examples.
2. Investigate applications of statistical techniques to interpret, organise and present data.
3. Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering applications.
4. Examine how differential and integral calculus can be used to solve engineering problems.

Essential Content

LO1 **Identify the relevance of mathematical methods to a variety of conceptualised engineering examples**

Mathematical concepts:

Dimensional analysis

Arithmetic and geometric progressions

Functions:

Exponential, logarithmic, trigonometric and hyperbolic functions

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

Summary of data:

Mean and standard deviation of grouped data

Pearson's correlation coefficient

Linear regression

Charts, graphs and tables to present data

Probability theory:

Binomial and normal distribution

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

Sinusoidal waves:

Sine waves and their applications

Trigonometric and hyperbolic identities

Vector functions:

Vector notation and properties

Representing quantities in vector form

Vectors in three dimensions

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

Differential calculus:

Definitions and concepts

Definition of a function and of 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 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 problems involving calculus:

Including: stress and strain, torsion, 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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Identify the relevance of mathematical methods to a variety of conceptualised engineering examples		**LO1 & LO2**
P1 Apply dimensional analysis techniques to solve complex problems **P2** Generate answers from contextualised arithmetic and geometric progressions **P3** Determine solutions of equations using exponential, logarithmic, trigonometric and hyperbolic functions	**M1** Use dimensional analysis to derive equations	**D1** Present data in a method that can be understood by a non-technical audience
LO2 Investigate applications of statistical techniques to interpret, organise and present data		
P4 Summarise data by calculating mean and standard deviation **P5** Calculate probabilities within both binomially distributed and normally distributed random variables	**M2** Interpret the results of a statistical hypothesis test conducted from a given scenario	

Pass	Merit	Distinction
LO3 Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering application		**D2** Model the combination of sine waves graphically and analyse the variation in results between graphical and analytical methods
P6 Solve engineering problems relating to sinusoidal functions **P7** Represent engineering quantities in vector form, and use appropriate methodology to determine engineering parameters	**M3** Use compound angle identities to combine individual sine waves into a single wave	
LO4 Examine how differential and integral calculus can be used to solve engineering problems		**D3** Analyse maxima and minima of increasing and decreasing functions using higher order derivatives
P8 Determine rates of change for algebraic, logarithmic and trigonometric functions **P9** Use integral calculus to solve practical problems relating to engineering	**M4** Formulate predictions of exponential growth and decay models using integration methods	

Recommended Resources

Textbooks

SINGH, K. (2011) *Engineering Mathematics Through Applications*. 2nd Ed. Basingstoke: Palgrave Macmillan.

STROUD, K.A. and BOOTH, D.J. (2013) *Engineering Mathematics*. 7th Ed. Basingstoke: Palgrave Macmillan.

Websites

http://www.mathcentre.ac.uk/	Maths Centre (Tutorials)
http://www.mathtutor.ac.uk/	Maths Tutor (Tutorials)

Links

This unit links to the following related units:

Unit 39: Further Mathematics

Unit 3: Engineering Science

Unit code T/615/1477

Unit type Core

Unit level 4

Credit value 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 forces, fluid mechanics and thermodynamics, material properties and failure, and A.C./D.C. circuit theories.

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, 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:

1. Examine scientific data using both quantitative and qualitative methods.
2. Determine parameters within mechanical engineering systems.
3. Explore the characteristics and properties of engineering materials.
4. 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**

International system of units:

The basic dimensions in the physical world and the corresponding SI base units

SI derived units with special names and symbols

SI prefixes and their representation with engineering notation

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

Using presentation software to present data to an audience

LO2 **Determine parameters within mechanical engineering systems**

Static and dynamic forces:

Representing loaded components with space and free body diagrams

Calculating support reactions of beams subjected to concentrated and distributed loads

Newton’s laws of motion, D’Alembert’s principle and the principle of conservation of energy

Fluid mechanics and thermodynamics:

Archimedes’ principle and hydrostatics

Continuity of volume and mass flow for an incompressible fluid

Effects of sensible/latent heat of fluid

Heat transfer due to temperature change and the thermodynamic process equations

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

Material properties:

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

Mechanical and electromagnetic properties of materials

Material failure:

Destructive and non-destructive testing of materials

The effects of gradual and impact loading on a material.

Degradation of materials and hysteresis

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

D.C. circuit theory:

Voltage, current and resistance in D.C. networks

Exploring circuit theorems (Thevenin, Norton, Superposition), Ohm's law and Kirchhoff's voltage and current laws

A.C. circuit theory:

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

RLC circuits

Magnetism:

Characteristics of magnetic fields and electromagnetic force

The principles and applications of electromagnetic induction

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine scientific data using both quantitative and qualitative methods</td><td rowspan="2">D1 Analyse scientific data using both quantitative and qualitative methods</td></tr>
<tr><td>P1 Describe SI units and prefix notation

P2 Examine quantitative and qualitative data with appropriate graphical representations</td><td>M1 Explain how the application of scientific method impacts upon different test procedures</td></tr>
<tr><td colspan="2">LO2 Determine parameters within mechanical engineering systems</td><td rowspan="2">D2 Compare how changes in the thermal efficiency of a given system can affect its performance.</td></tr>
<tr><td>P3 Determine the support reactions of a beam carrying a combination of a concentrated load and a uniformly distributed load

P4 Use Archimedes’ principle in contextual engineering applications

P5 Determine the effects of heat transfer on the dimensions of given materials</td><td>M2 Determine unknown forces by applying d'Alembert's principle to a free body diagram</td></tr>
</table>

Pass	Merit	Distinction
LO3 Explore the characteristics and properties of engineering materials		**D3** Compare and contrast theoretical material properties of metals and non-metals with practical test data
P6 Describe 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	
LO4 Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties		**D4** Evaluate different techniques used to solve problems on a combined series-parallel RLC circuit using A.C. theory.
P8 Calculate currents and voltages in D.C. circuits using circuit theorems **P9** Describe how complex waveforms are produced from combining two or more sinusoidal waveforms. **P10** Solve problems on series RLC circuits with A.C. theory.	**M4** Explain the principles and applications of electromagnetic induction	

Recommended Resources

Textbooks

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

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

TOOLEY, M. and DINGLE, L. (2012) *Engineering Science: For Foundation Degree and Higher National*. London: Routledge.

Journals

International Journal of Engineering Science.

International Journal of Engineering Science and Innovative Technology.

Websites

https://www.khanacademy.org/	Khan Academy Physics (Tutorials)

Links

This unit links to the following related units:

Unit 9: Materials, Properties and Testing

Unit 3: Engineering Science

Unit 4: Managing a Professional Engineering Project

Unit code **A/615/1478**

Unit level **4**

Credit value **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 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, and 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 assignment. 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:

1. Formulate and plan a project that will provide a solution to an identified engineering problem.
2. Conduct planned project activities to generate outcomes which provide a solution to the identified engineering problem.
3. Produce a project report analysing the outcomes of each of the project processes and stages.
4. Present the project report drawing conclusions on the outcomes of the project.

Essential Content

LO1 **Formulate and plan a project that will provide a solution to an identified engineering problem**

Examples of realistic engineering-based problems:

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

Develop an outline project brief and design specification:

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

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

The role and responsibilities of the UK Engineering Council and Professional Engineering Institutions (PEIs)

The content of the UK Standard for Professional Engineering Competence (UK-SPEC)

Chartered Engineer, Incorporated Engineer and Engineering Technician

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

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 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

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 (UK-SPEC)

Professional standards of behaviour (UK-SPEC)

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

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

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: who to invite – project supervisors, fellow students and employers. 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

Reflective writing:

Avoiding generalisation and focusing on personal development and the research journey in a critical and objective way

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Formulate and plan a project that will provide a solution to an identified engineering problem		**D1** Illustrate the effect of legislation and ethics in developing the project plan
P1 Select an appropriate engineering based project, giving reasons for the selection **P2** Create a project plan for the engineering project	**M1** Undertake a feasibility study to justify project selection	
LO2 Conduct planned project activities to generate outcomes which provide a solution to the identified engineering problem		**D2** Critically evaluate the success of the project plan making recommendations for improvements
P3 Conduct project activities, recording progress against original project plan	**M2** Explore alternative methods to monitor and meet project milestones, justify selection of chosen method(s)	
LO3 Produce a project report analysing the outcomes of each of the project processes and stages		**LO3 & LO4** **D3** Critically analyse the project outcomes making recommendations for further development
P4 Produce a project report covering each stage of the project and analysing project outcomes	**M3** Use appropriate critical analysis and evaluation techniques to analyse project findings	
LO4 Present the project report drawing conclusions on the outcomes of the project		
P5 Present the project report using appropriate media to an audience	**M4** Analyse own behaviours and performance during the project and suggest areas for improvement	

Recommended Resources

Textbooks

PUGH, P. S. (1990) *Total Design: Integrated Methods for Successful Product Engineering*. Upper Saddle River: Prentice-Hall.
STRIEBIG, B., OGUNDIPE, A. and PAPADAKIS, M. (2015) *Engineering Applications in Sustainable Design and Development*. Boston: Cengage Learning.

ULRICH, K. and EPPINGER, S. (2011) *Product Design and Development*. 5th Ed. Columbus: McGraw-Hill Higher Education.

Journals

Journal of Engineering Design

Links

This unit links to the following related units:

Unit 34: Research Project

Unit 35: Professional Engineering Management

Unit 5: Renewable Energy

Unit code F/615/1479

Unit level 4

Credit value 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.

The aim of this unit is to introduce students to renewable energy resources and technologies, including current storage and generation technologies, and explore their advantages and limitations.

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:

1. Explore potential renewable energy resources, including current storage and generation technologies.
2. Determine the optimum combination and efficiencies of renewable energy technologies for a particular location.
3. Conduct a cost–benefit analysis to determine the most viable option between renewable and conventional energy sources.
4. Explain socio-economic, legislative and environmental factors involved in the consideration and selection of other approaches to renewable energy resources and technologies.

Essential Content

LO1 **Explore potential renewable energy resources, including current storage and generation technologies**

Alternative energy sources, their respective merits and drawbacks:

Wind energy, ocean and tidal energy, biomass, geothermal energy, hydropower, solar and thermal energy

Waste as energy

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, 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 UK and local areas

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

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

Socio-economic factors

Financial implications of renewable and conventional energy

LO4 **Explain socio-economic, legislative and environmental factors involved in the consideration and selection of other approaches to renewable energy resources and technologies**

Environmental factors of the set-up and operation of renewable technologies:

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

Evaluation planning tools such as PESTLE analysis

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore potential renewable energy resources, including current storage and generation technologies		**D1** Provide supported and well justified recommendations for the adoption of the most widely used conventional and non-conventional renewable energy resources
P1 Create schematic diagrams showing the working principle of the most widely used renewable energy systems	**M1** Explore the rates of adoption of the most widely used renewable energy resources	
LO2 Determine the optimum combination and efficiencies of renewable energy technologies for a particular location		**D2** Summarise the efficiencies of a variety of combinations of renewable energy technologies for a chosen location
P2 Describe how each renewable energy system could be connected with local energy systems	**M2** Discuss how renewable energy systems will bring benefit to the people living in the chosen area	
LO3 Conduct a cost–benefit analysis to determine the most viable option between renewable and conventional energy sources		**D3** Conduct a cost–benefit critical analysis to determine the most viable option between all available renewable and conventional energy sources
P3 Calculate the installation and construction costs of one renewable energy system from a renewable energy standpoint	**M3** Contrast the installation and construction costs of all available renewable energy sources	
LO4 Explain socio-economic, legislative and environmental factors involved in the consideration and selection of other approaches to renewable energy resources and technologies		**D4** Provide supported and justified recommendations and original ideas for an effective environmental analysis of alternative approaches to the selection of renewable energy resources
P4 Examine how socio-economic, legislative and environmental factors affect the selection, set-up and operation of renewable energy sources	**M4** Evaluate environmental analysis and planning tools such as PESTLE to identify possible sources of conflicts of interest	

Recommended Resources

Textbooks

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

BOTKIN, D. (2010) *Powering the Future*. Pearson.

BOYLE, G. and Open University (2008) *Renewable Energy*. 3rd Ed. Oxford: Oxford University Press.

EVERETT, B., BOYLE, G. and PEAKE, S. (2011) *Energy systems and sustainability: Power for a Sustainable Future*. 2nd Ed. Oxford University Press.

TESTER, J. (2005) *Sustainable Energy: Choosing Among Options*. London: MIT Press.

Journals

Renewable Energy Focus Journal.

The Open Renewable Energy Journal.

Journal of Renewable and Sustainable Energy.

Renewable Energy: An International Journal.

Websites

https://www.theguardian.com	The Guardian Renewable energy (Articles)
http://www.energysavingtrust.org.uk/	Energy Saving Trust Renewable energy (General Reference)
http://www.gov.uk/	Gov.UK Department of Energy & Climate Change (General Reference)

Links

This unit links to the following related units:

Unit 4: Managing a Professional Engineering Project

Unit 44: Industrial Power, Electronics and Storage

Unit 51: Sustainability

Unit 6: Mechatronics

Unit code T/615/1480

Unit level 4

Credit value 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 explain the basic mechatronic system components and functions, design a simple mechatronic system specification for a given application, use appropriate simulation and modelling software to examine its operation and function, and solve faults on mechatronic systems using a range of techniques and methods.

Learning Outcomes

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

1. Explain the design and operational characteristics of a mechatronic system.
2. Design a mechatronic system specification for a given application.
3. Examine the operation and function of a mechatronics system using simulation and modelling software.
4. Identify and correct faults in a mechatronic system.

Essential Content

LO1 **Examine the design and operational characteristics of a mechatronic system**

Origins and evolution:

History and early development, evolution

Practical examples and extent of use

Current operational abilities and anticipated improvements

Systems characteristics:

Design of systems in an integrated way

Sensor and transducer types used

Consideration of component compatibility

Constraints on size and cost

Control device requirements and examples of applications

LO2 **Design a mechatronic system specification for a given application**

Systems specifications:

British and/or European standards relevant to application

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 **Identify and correct faults in a mechatronic system**

Locating and correcting system faults:

Component data sheets, systems drawings, flowcharts, wiring and schematic diagrams

Original system correct function and operation

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the design and operational characteristics of a mechatronic system		**D1** Investigate an actual mechatronics system specification to propose alternative solutions
P1 Describe the key components of a given mechatronics system **P2** Identify the types of actuators, sensors and transducers used in the mechatronics system	**M1** Explore how the mechatronics components operate as part of an integrated system **M2** Investigate the methods of control used by mechatronics systems	
LO2 Design a mechatronic system specification for a given application		**D2** Evaluate the operational capabilities and limitations of the mechatronics system design specification produced
P3 Select the relevant sensor and the appropriate actuator technologies and produce a design specification suitable for these selections	**M3** Justify the sensor and actuator technologies selected with reference to available alternatives	
LO3 Examine the operation and function of a mechatronics system using simulation and modelling software		**D3** Explain the function and operation of a simulated mechatronics system
P4 Demonstrate industry standard mechatronics simulation/modelling software	**M4** Describe the advantages and disadvantages of the software simulation	
LO4 Identify and correct faults in a mechatronic system		**D4** Investigate the causes of faults on a mechatronics system and suggest alternatives to the design specification to improve reliability
P5 Explain the safe use of fault finding test equipment **P6** Locate and rectify faults on a mechatronic system	**M5** Apply and document the correct use of fault finding techniques/methods	

Recommended Resources

Textbooks

BOLTON, W. (2015) *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*. 5th Ed. Essex: Pearson Education Limited.

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.

Journals

International Journal of Advanced Mechatronic Systems.

Links

This unit links to the following related units:

Unit 15: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 54: Fundamentals of Control Systems

Unit 7: Machining and Processing of Engineering Materials

Unit code A/615/1481

Unit level 4

Credit value 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, 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 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:

1. Explore the conventional machining and forming processes and their application in the production of engineered components.
2. Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process.
3. Identify the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component.
4. Identify 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 and forming processes and their application in the production of engineered components**

Conventional 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

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

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

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 **Identify 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 **Identify 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

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

Pass	Merit	Distinction
LO1 Explore the conventional machining and forming processes and their application in the production of engineered components		**D1** Determine the benefits and limitations of components manufactured using conventional machining and moulding processes
P1 Describe the most appropriate machining process to manufacture a selected product **P2** Explain why a specific machining process would be used to manufacture a selected component	**M1** Examine the characteristics of conventional machining processes, plastic moulding processes and powder metallurgy	
LO2 Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process		**D2** Review the structure and mechanical properties of a given engineered aluminium alloy component, manufactured using the die casting process and conventional material removal machining processes
P3 Describe 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	**M2** Detail the characteristics of cutting tool geometries **M3** Explain why different tool geometries are required for polymer, composite and carbon steel materials	
LO3 Identify the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component		**D3** Examine the relationship between cutting speed and tool life on the economics of metal removal
P5 Review the parameters that determine the appropriate tooling for the production of a given engineered component **P6** Describe the six modes of cutting tool failure	**M4** Explain the properties and applications of ceramics tools and cubic boron nitride tools	

Pass	Merit	Distinction
LO4 Identify the most appropriate moulding and shaping process used to produce a range of metal and non-metal engineered components		**D4** Investigate how the composition and structure of metal alloys, polymers and polymer matrix composites are affected by the material machining or forming process
P7 Explain which material characteristics determine the choice of plastic moulding process **P8** Describe the benefits and limitations of products manufactured by the sintering process	**M5** Explain each of the stages of the ceramic powder moulding process and comment on the benefits associated with this manufacturing process	

Recommended Resources

Textbooks

KALPAKJIAN, S. and SCHMID, R.S. (2013) *Manufacturing Engineering and Technology*. 7th Ed. Pearson.

TIMINGS, R.L. (2004) *Basic Manufacturing*. 3rd Ed. Oxford: Newnes.

Journals

Journal of Materials: Design and Applications.

Websites

http://www.machinery.co.uk/	Machinery (General Reference)
http://www.materialsforengineering.co.uk/	Engineering Materials Online Magazine (E-Magazine)

Links

This unit links to the following related units:

Unit 9: Materials, Properties and Testing

Unit 10: Mechanical Workshop Practices

Unit 8: Mechanical Principles

Unit code F/615/1482

Unit level 4

Credit value 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, among 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 unit will 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; movement and transfer of energy by considering parameters of mechanical power transmission systems.

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

Learning Outcomes

1. Identify solutions to problems within static mechanical systems.
2. Illustrate the effects that constraints have on the performance of a dynamic mechanical system.
3. Investigate elements of simple mechanical power transmission systems.
4. Analyse natural and damped vibrations within translational and rotational mass-spring systems.

Essential Content

LO1 **Identify solutions to 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 beams and columns to satisfy given specifications

The theory of torsion in solid and hollow circular shafts

LO2 **Illustrate the effects that constraints have on the performance of a dynamic mechanical system**

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

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

Simple systems:

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

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Identify solutions to problems within static mechanical systems		**D1** Calculate the magnitude of shear force and bending moment in cantilever and encastré beams for a variety of applications
P1 Calculate the 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** Determine the distribution of shear stress and the angular deflection due to torsion in solid and hollow circular shafts	**M1** Determine the material of a circular bar from experimental data of angle of twist obtained from a torsion test	
LO2 Illustrate the effects that constraints have on the performance of a dynamic mechanical system		**D2** Calculate solutions of velocities and accelerations within planar mechanisms using trigonometric methodology
P4 Explain the effects of energy transfer in mechanical systems with uniform acceleration present **P5** Identify the magnitude and effect of gyroscopic reaction torque	**M2** Construct diagrams of the vector solutions of velocities and accelerations within planar mechanisms	

Pass	Merit	Distinction
LO3 Investigate elements of simple mechanical power transmission systems		**D3** Examine the cause of a documented case of mechanical power transmission failure and the steps taken to correct the problem and rectify any design faults
P6 Determine the velocity ratio for compound gear systems and the holding torque required to securely mount a gearbox **P7** Calculate 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** Identify the conditions needed for mechanical resonance and measures that are taken to prevent this from occurring
P9 Explain the natural frequency of vibration in a mass-spring system	**M4** Determine the amplitude and phase angle of the transient response within a mass-spring-damper system	

Recommended Resources

Textbooks

BIRD, J. and ROSS, C. (2014) *Mechanical Engineering Principles*. 3rd Ed. London: Routledge.

TOOLEY, M. and DINGLE, L. (2012) *Engineering Science: For Foundation Degree and Higher National*. London: Routledge.

Websites

https://www.khanacademy.org/	Khan Academy (Tutorials)

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 2: Engineering Maths

Unit 36: Advanced Mechanical Principles

Unit 9: Materials, Properties and Testing

Unit code J/615/1483

Unit level 4

Credit value 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 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 physical properties of materials, determine the suitability of engineering materials for use in a specified role, explore the testing techniques to determine the physical properties of an engineering material and identify the causes of in-service material failure.

Learning Outcomes

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

1. Explain the relationship between the atomic structure and the physical properties of materials.
2. Determine the suitability of engineering materials for use in a specified role.
3. Explore the testing techniques to determine the physical properties of an engineering material.
4. Recognise and categorise the causes of in-service material failure.

Essential Content

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

Physical properties of materials:

Classification and terminology of engineering materials

Material categories: metallic, ceramic, polymer and composites

Atomic structure, electrostatic covalent and ionic bonding

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

Characteristics and function of ferrous, non-ferrous phase diagrams, amorphous and crystalline polymer structures

LO2 **Determine the suitability of engineering materials for use in a specified role**

Materials used in specific roles:

The relationship between product design and material selection

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

The effect heat treatment and mechanical processes have on material properties

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

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

LO3 **Explore the testing techniques to determine the physical 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 compare results against industry recognised data sources, explain reasons for any deviation found

LO4 **Recognise and categorise the causes of in-service material failure**

Material failure:

Reasons why engineered components fail in service

Working and environmental conditions that lead to material failure

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

Reasons for failure in service

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 physical properties of materials		**D1** Explain how composition and structure of materials influence the properties of the parent material across the material's range
P1 Describe the crystalline structure of the body-centred cubic cell, face-centred cubic cell and hexagonal close packed cell **P2** Identify the different material properties that are associated with amorphous and crystalline polymer structures	**M1** Describe physical, mechanical, electrical and thermal material properties, identifying practical applications for each property if it were to be used in an engineering context	
LO2 Determine the suitability of engineering materials for use in a specified role		**D2** Explain why the behaviour of materials is considered such an important factor when selecting a material for a given product or application
P3 Provide a list of the four materials categories, including an example of a product and application for each material identified **P4** Identify the specific characteristics related to the behaviour of the four categories of engineering materials	**M2** Describe, with examples, the effect heat treatment and mechanical processes have on material properties	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Explore the testing techniques to determine the physical properties of an engineering material</td><td rowspan="2">D3 Analyse the results of mechanical tests on each of the four material categories for data comparison and compare results against industry recognised data sources, explaining any differences found</td></tr>
<tr><td>P5 Describe the six most common tests used to identify material properties

P6 Describe the non-destructive testing processes – dye penetrant, magnetic particle, ultrasonic and radiography – and include an example application for each</td><td>M3 Explain how test results influence material selection for a given application</td></tr>
<tr><td colspan="2">LO4 Recognise and categorise the causes of in-service material failure</td><td rowspan="2">D4 Explain the methods that could be used for estimating product service life when a product is subject to creep and fatigue loading</td></tr>
<tr><td>P7 Describe six common mechanisms of failure

P8 Describe working and environmental conditions that lead to failure for a product made from material from each of the four material categories</td><td>M4 Explain, with examples, the preventative measures that can be used to extend the service life of a given product within its working environment</td></tr>
</table>

Recommended Resources

Textbooks

ASHBY, M. (2005) *Materials Selection in Mechanical Design.* 3rd Ed. Elsevier.

CALLISTER, W. and RETHWISCH, D. (2009) *Fundamentals of Materials Science and Engineering: An Integrated Approach*. 4th Ed. Wiley.

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 10: Mechanical Workshop Practices

Unit 10: Mechanical Workshop Practices

Unit code	**L/615/1484**
Unit level	**4**
Credit value	**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 identify the mechanical measurement and quality control processes to analyse the dimensional accuracy of a machined component; operate machining equipment to produce a range of components to specification; explain the importance of material selection when choosing the most appropriate machining process; and apply safe working practices throughout.

Learning Outcomes

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

1. Identify 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.
2. Operate a manual lathe and milling machine to produce dimensionally accurate engineering components.
3. Interpret information from engineering drawings and operate measuring tools and work-holding equipment to check dimensional accuracy of machined components.
4. Explain mechanical measurement and quality control processes.

Essential Content

LO1 **Identify 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

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

Risk assessment of bench fitting and machining activities

LO2 **Operate a manual lathe and milling machine to produce dimensionally accurate engineering components**

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 and application

Use of work-holding jigs and fixtures

Removing material within dimensional tolerances

LO3 **Interpret information from engineering drawings and 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 the types and use of 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 Identify 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		**D1** Interpret the key features of relevant health and safety regulations as applied to a machining workshop
P1 Identify the potential hazards that exist when operating machine tools and bench fitting equipment **P2** Describe 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	
LO2 Operate a manual lathe and milling machine to produce dimensionally accurate engineering components		**D2** Illustrate the operating parameters of the milling machine and lathe and describe the function and features of cutting tools, work and tool-holding devices
P3 Produce a dimensionally accurate component using a lathe and milling machine	**M2** Calculate appropriate cutting speeds and feeds to suit material properties and application for a given component	

Pass	Merit	Distinction
LO3 Interpret information from engineering drawings and operate measuring tools and work-holding equipment to check dimensional accuracy of machined components		**D3** Examine, with reference to material properties and geometry, the criteria for selection of the appropriate tooling for machining components from engineering materials including aluminium alloy, stainless steel and titanium alloy
P4 Identify the information that is required from a drawing to plan, machine and check the accuracy of a complex engineering component **P5** Describe the function of precision measuring equipment used to check the dimensional accuracy of machined components	**M3** Explain the process of using a dial gauge indicator to set-up work-holding devices on a milling machine	
LO4 Explain the types and use of mechanical measurement and quality control processes		**D4** Illustrate why the process of machining data collection and analysis is of critical importance to a production engineering company
P6 Explain the purpose of an engineering metrology laboratory and list the equipment found in a typical such lab	**M4** Determine the function of the metrology equipment, surface testing, profile projectors, video measuring, interferometer, SIP measuring equipment, coordinate measuring machines (CMM) and 3D scanners	

Recommended Resources

Textbooks

BADADHE, A.M. (2006) *Metrology and Quality Control*.
Tathawade: Technical Publications.

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

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

NUBUO, S. (2007) *Metrology Handbook: The Science of Measurement*. 5th Ed. Mitutoyo (UK) Ltd.

RAGHAVENDRA, N.V. and KRISHNAMURTHY, L. (2013) *Engineering Metrology and Measurements*. Oxford University Press.

Journals

International Journal of Metrology and Quality Engineering.

Metrology Journal.

Links

This unit links to the following related units:

Unit 9: Materials, Properties and Testing

Unit 14: Production Engineering for Manufacture

Unit 11: Fluid Mechanics

Unit code R/615/1485

Unit level 4

Credit value 15

Introduction

Fluid mechanics is an important subject to 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, while civil engineers concentrate on water supply, sewerage and irrigation.

This unit introduces students to the fluid mechanics techniques used in mechanical engineering. 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 work with the concept and measurement of viscosity in fluids, and the characteristics of Newtonian and non-Newtonian fluids; examine fluid flow phenomena, including energy conservation, estimation of head loss in pipes and viscous drag; and examine 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:

1. Determine the behavioural characteristics of static fluid systems.
2. Examine the operating principles and limitations of viscosity measuring devices.
3. Investigate dynamic fluid parameters of real fluid flow.
4. Explore dynamic fluid parameters of real fluid flow.

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 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:

Dynamic and kinematic viscosity definitions

Characteristics of Newtonian fluids

Temperature effects on viscosity

Classification of non-Newtonian fluids

Operating principles and limitations:

Operating principles of viscometers

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 how drag induces lift

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 these different types of hydraulic machinery

Environmental concerns surrounding hydraulic machines

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine behavioural characteristics of static fluid systems		**D1** Explain the use and limitations of manometers to measure pressure
P1 Describe force and centre of pressure on submerged surfaces **P2** Carry out appropriate calculations on force and centre of pressure on submerged surfaces	**M1** Determine the parameters of hydraulic devices that are used in the transmission of force	
LO2 Examine the operating principles and limitations of viscosity measuring devices		**D2** Illustrate the results of a viscosity test on a Newtonian fluid at various temperatures with that which is given on a data sheet and explain discrepancies
P3 Explain 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	
LO3 Investigate dynamic fluid parameters of real fluid flow		**D3** Determine the head losses accumulated by a fluid when flowing in a pipeline for various applications
P5 Determine parameters of a flowing fluid using Bernoulli's Equation **P6** Define 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	

Pass	Merit	Distinction
LO4 Explore the operating principles and efficiencies of hydraulic machines		**D4** Describe and analyse the arguments concerning the ecological impact of hydroelectric power
P7 Determine the efficiency of a water turbine **P8** Calculate the input power requirements of centrifugal pumps	**M4** Identify the limitations that exist within different types of water turbine	

Recommended Resources

Textbook

MASSEY, B.S. and WARD-SMITH, J. (2011) *Mechanics of Fluids*. 9th Ed. Oxford: Spon Press.

Journals

Journal of Fluid Mechanics. Cambridge University Press.

Annual Review of Fluid Mechanics. Annual Reviews, California.

Websites

https://www.khanacademy.org/	Khan Academy Fluids (Tutorials)

Links

This unit links to the following related units:

Unit 29: Electro, Pneumatic and Hydraulic Systems

Unit 64: Thermofluids

Unit 12: Engineering Management

Unit code Y/615/1486

Unit level 4

Credit value 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

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

1. Examine the application of management techniques, and cultural and leadership aspects to engineering organisations.
2. Explore the role of risk and quality management in improving performance in engineering organisations.
3. Investigate the theories and tools of project and operations management when managing activities and optimising resource allocation.
4. 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		**D1** Propose recommendations for the most efficient application of management techniques
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	
LO2 Explore the role of risk and quality management in improving performance in engineering organisations		**D2** Provide supported and justified recommendations for the most efficient and effective risk and quality management practices
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	
LO3 Investigate the theories and tools of project and operations management 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
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	

Pass	Merit	Distinction
LO4 Perform activities that improve current management strategies within an identified element of 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
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	

Recommended Resources

Textbooks

BOWERSOX, D.J., CLOSS, D. and BIXBY, M. (2012) *Supply Chain Logistics Management*. 4th Ed. McGraw-Hill.

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

OAKLAND, J.S. (2015) *Statistical Process Control*. 6th Ed. 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 4: Managing a Professional Engineering Project

Unit 35: Professional Engineering Management

Unit 13: Fundamentals of Thermodynamics and Heat Engines

Unit code D/615/1487

Unit level 4

Credit value 15

Introduction

Thermodynamics is one of the most common applications of science in our lives. It is so much a part of our daily life that it is often taken for granted. For example, when driving your car you know that the fuel you put into the tank is converted into 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 investigate fundamental thermodynamic systems and their properties; apply the steady flow energy equation to plant equipment; examine the principles of heat transfer in industrial applications; and determine the performance of internal combustion engines.

Learning Outcomes

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

1. Investigate fundamental thermodynamic systems and their properties.
2. Apply the steady flow energy equation to plant equipment.
3. Examine the principles of heat transfer in industrial applications.
4. Determine the performance of internal combustion engines.

Essential Content

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

Fundamental systems:

Forms of energy and basic definitions

Definitions of systems (open and closed) and surroundings

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 and isothermal systems

LO2 **Apply the steady flow energy equation to plant equipment**

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 **Examine the principles of heat transfer in industrial applications**

Principles of heat transfer:

Modes of heat transmission including conduction, convection and radiation

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

Application of formulae to different types of heat exchangers including recuperator and evaporative

Regenerators

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

LO4 **Determine the performance of internal combustion engines**

Performance:

Application of the second law of thermodynamics to heat engines

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 engines, including their relative mechanical and thermodynamic efficiencies

Description of possible efficiency improvements to heat engines

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate fundamental thermodynamic systems and their properties		**D1** Illustrate the importance of expressions for work done in thermodynamic processes by applying first principles
P1 Describe the operation of thermodynamic systems and their properties **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** Calculate the index of compression in polytrophic processes	
LO2 Apply the steady flow energy equation to plant equipment		**D2** Produce specific steady flow energy equations based on stated assumptions in plant equipment
P4 Explain system parameters using the non-flow energy equation **P5** Apply the steady flow energy equation to plant equipment	**M2** Derive the steady flow energy equation from first principles	
LO3 Examine the principles of heat transfer in industrial applications		**D3** Distinguish the differences between parallel and counter-flow recuperator heat exchangers
P6 Determine the heat transfer through composite walls **P7** Apply heat transfer formulae to heat exchangers	**M3** Explore heat losses through lagged and unlagged pipes	

Pass	Merit	Distinction
LO4 Determine the performance of internal combustion engines		**D4** Evaluate the performance of two-stroke and four-stroke diesel engines
P8 Describe with the aid of diagrams the operational sequence of four-stroke spark ignition and four-stroke compression ignition engines **P9** Explain the mechanical efficiency of two and four-stroke engines	**M4** Review the relative efficiency of ideal heat engines operating on the Otto and Diesel cycles	

Recommended Resources

Textbooks

DUNN, D. (2001) *Fundamental Engineering Thermodynamics*. Harlow: Longman.

EASTOP, T. D. and MCCONKEY, A. (1996) *Applied Thermodynamics for Engineering Technologists.* 5th Ed. Upper Saddle River: Prentice-Hall.

EASTOP, T. D. and MCCONKEY, A. (1997) *Applied Thermodynamics for Engineering Technologists Student Solution Manual.* 5th Ed. Upper Saddle River: Prentice-Hall.

RAYNER, J. (2008) *Basic Engineering Thermodynamics.* 5th Ed. London: Pearson.

ROGERS, G. F. C and MAYHEW, Y. R. (1994) T*hermodynamic and Transport Properties of Fluids: S. I. Units.* 5th Ed. Hoboken: Wiley-Blackwell.

Links

This unit links to the following related unit:

Unit 38: Further Thermodynamics

Unit 14: Production Engineering for Manufacture

Unit code H/615/1488

Unit level 4

Credit value 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 illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system, select the most appropriate production processes and associated facility arrangements for manufacturing products of different material types, design a production system incorporating a number of different production processes for a given product or assembly and explore the effectiveness of a production system in terms of its operation within the wider manufacturing system.

Learning Outcomes

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

1. Illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system.
2. Select the most appropriate production processes and associated facility arrangements, for manufacturing products of different material types.
3. Analyse how a production system can incorporate a number of different production processes for a given product or assembly.
4. 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 and systems for producing quality products

Design, implement and refine products, services, processes and systems

Combination of manufacturing technology and management science

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

Production processes:

Common ceramics, composite, metals manufacturing processes

Bonding and jointing technologies, including welding, adhesives, snap fits, 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

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

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

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

The human component:

Cultural openness to new ideas and continuous improvement

Collaboration and information sharing

Performance management and rewards

Engineer training and development practices

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system		**D1** Analyse how the production engineer supports the development of operational strategies to achieve production and financial objectives
P1 Describe the multiple elements of a modern manufacturing system **P2** Explain the role of the production engineer within a manufacturing system	**M1** Investigate how the production engineer can influence the design process and refine products, services and systems	
LO2 Select the most appropriate production processes and associated facility arrangements for manufacturing products of different material types		**D2** Evaluate how the choice of bonding and jointing processes influence both the product design and the selection of the most effective production process
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 lay-up, filament winding, pultrusion and resin transfer moulding processes	**M2** Discuss the benefits associated with polymer manufacturing process	

Pass	Merit	Distinction
LO3 Analyse how a production system can incorporate a number of different production processes for a given product or assembly		**D3** Analyse the relationship 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
P5 Review the type and sequence of production processes a product or component would follow from initial design through to manufacture and distribution **P6** Describe the function of the various production facilities within a modern manufacturing plant	**M3** Explain how materials, components and sub-assembly handling and conveyance can impact on the effectiveness and efficiency of a modern manufacturing plant	
LO4 Explore the effectiveness of a production system in terms of its operation within the wider manufacturing system		**D3** Analyse the criteria by which production performance can be measured within the wider manufacturing system
P7 Review the type of data that would be collected and analysed to measure production performance **P8** Describe 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	

Recommended Resources

Textbooks

KALPAKJIAN, S. and SCHMID, S. (2009) *Manufacturing Engineering and Technology*. 6th Ed. Prentice Hall.

Websites

https://www.khanacademy.org/	Khan Academy (Tutorials)

Links

This unit links to the following related units:

Unit 23: Computer Aided Design and Manufacture (CAD/CAM)

Unit 48: Manufacturing Systems Engineering

Unit 15: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit code	**K/615/1489**
Unit level	**4**
Credit value	**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 program PLCs and robotic manipulators to achieve a set task, describe the types and uses of PLCs and robots available, write simple PLC programs, and program industrial robots with straightforward commands and safety factors.

Learning Outcomes

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

1. Describe the design and operational characteristics of a PLC system.
2. Design a simple PLC program by considering PLC information, programming and communication techniques.
3. Describe the key elements of industrial robots and be able to program them with straightforward commands to perform a given task.
4. 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)

Internal architecture

Different types of programming languages (IEC 61131-3)

LO2 **Design a simple PLC program by considering 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)

Test and debug methods:

Systematic testing and debugging methods

Proper application of appropriate testing and debugging methods

LO3 **Describe the key elements of industrial robots and be able to program them with straightforward commands to perform a given task**

Element considerations:

Types of robots

Mobile robotics

Tools and end effectors

Programming methods

Robot manipulators (kinematics, design, dynamics and control, vision systems, user interfaces)

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

Safety:

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 construction styles 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 simple PLC program by considering PLC information, programming and communication techniques		**D2** Produce all elements of a PLC program for a given industrial task and analyse its performance
P4 Design and describe the design elements that have to be considered in the preparation of a PLC programme program **P5** Explain how communication connections are correctly used with the PLC	**M2** Examine the methods used for testing and debugging the hardware and software	
LO3 Describe the key elements of industrial robots and be able to program them with straightforward commands to perform a given task		**D3** Design and produce a robot program for a given industrial task
P6 Describe the types of industrial robots and their uses in industry **P7** Describe the types of robot end effectors available and their applications	**M3** Investigate a given industrial robotic system and make recommendations for improvement	

Pass	Merit	Distinction
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 to include 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

Textbooks

BOLTON, W. (2015) *Programmable Logic Controllers*. 5th Ed. Elsevier.

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

PEREZ ANDROVER, E. (2012) *Introduction to PLCs: A beginner's guide to Programmable Logic Controllers*. Juncos: Elvin Peres Adrover

Websites

http://www.plcmanual.com/	PLC Manual (General Reference)
http://www.plcs.net/	PLC Programming Info (General Reference)
http://www.learnaboutrobots.com/	Learn About Robots Industrial Robots (General Reference)

Links

This unit links to the following related units:

Unit 6: Mechatronics

Unit 42: Further Programmable Logic Controllers (PLCs)

Unit 16: Instrumentation and Control Systems

Unit code D/615/1490

Unit level 4

Credit value 15

Introduction

Instrumentation and control can also be described as measurement automation, which is a very important area of engineering and manufacturing. 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 the controlling of a process 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 explain why the measurement of system parameters is critical to a successful process control performance, describe when and how such measurements are carried out, and develop 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:

1. Identify the instrumentation systems and devices used in process control.
2. Investigate the industrial process control systems.
3. Analyse the control concepts and technologies used within an industrial process.
4. Apply predicted values to ensure stability within a control system.

Essential Content

LO1 **Identify the instrumentation systems and devices used in process control**

Instrumentation systems:

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

Instrumentation signal terminology:

The importance of instrumentation signal terminology, including accuracy, error, drift, repeatability, 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

Process controller terminology:

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

LO3 **Analyse the control concepts used within a process**

System terminology and concepts:

Recognise system terminology and concepts, including distance velocity lags, capacity, resistance, static and dynamic gain, stability, feedback types, open and closed loop, feed forward control and control algorithms

System tuning techniques:

Investigate 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:

Apply predicted values to a control system using simulation to investigate system response accuracy, responses to a range of input signal types, stability of the system and possible improvements

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Identify the instrumentation systems and devices used in process control</td><td rowspan="2">D1 Critically review the industrial application of an instrumentation and control process system, using research evidence</td></tr>
<tr><td>P1 Define the types of sensor and transducers used in process control

P2 Describe how the sensors and transducers function

P3 Define the signal terminology used in process control

P4 Explain the different methods and standards used in signal conversion and conditioning</td><td>M1 Explore industrial applications for sensors and transducers

M2 Analyse the accuracy of the sensors and transducers used in a particular application</td></tr>
<tr><td colspan="2">LO2 Investigate process control systems and controllers</td><td rowspan="2">D2 Develop a recommendation for improvement to process control systems and controllers</td></tr>
<tr><td>P5 Describe the importance of process control systems

P6 Define the process controller terminology used in industrial applications</td><td>M3 Explain a typical industrial application for a process control system</td></tr>
</table>

Pass	Merit	Distinction
LO3 Analyse the control concepts used within a process		**D3** Analyse the effectiveness of the control concepts used within a given process and suggest improvements
P7 Define the control terminology and concepts used in process control systems **P8** Describe the system tuning methods and techniques employed to improve performance	**M4** Explain the control terminology, concepts and tuning techniques used in a typical industrial application	
LO4 Apply predicted values to ensure stability within a control system		**D4** Discuss why the system responds in a certain way as the signals are applied
P9 Demonstrate the correct use of an instrumentation and control virtual simulation	**M5** Show how the virtual control system responds to a range of signal inputs	

Recommended Resources

Textbooks

BOLTON, W. (2015) *Instrumentation and Control Systems*. 2nd Ed. Newnes.

ESSICK, J. (2012) *Hands-On Introduction to LabVIEW for Scientists and Engineers*. 2nd Ed. Oxford University Press.

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

Journals

Journal of Process Control.

Links

This unit links to the following related units:

Unit 40: Commercial Programming Software

Unit 54: Fundamentals of Control Systems

Unit 17: Quality and Process Improvement

Unit code H/615/1491

Unit level 4

Credit value 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:

1. Illustrate the applications of statistical process control when applied in an industrial environment to improve efficiency.
2. Analyse cost effective quality control tools.
3. Determine the role of standards in improving efficiency, meeting customer requirements and opening up new opportunities for trade.
4. Analyse the importance of Total Quality Management and continuous improvement in manufacturing environments.

Essential Content

LO1 **Illustrate 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 SPC

Designing quality into new products and processes using Quality Function Deployment (QFD)

LO2 **Analyse cost effective quality control tools**

Quality costing:

Costing modules

The importance of qualifying the costs related to quality

How costs can be used to improve business performance

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 and industry

Standards for measurement

International Standards for management (ISO 9000, 14000, 18000)

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

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

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

Understanding and implementation of Six Sigma

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Illustrate the applications of statistical process control when applied in an industrial environment to improve efficiency		**D1** Suggest justified recommendations for the application of statistical process control in an industrial environment to improve efficiency
P1 Review the tools and techniques used to support quality control **P2** Describe the processes and applications of statistical process control in industrial environments	**M1** Explain the role and effectiveness of the quality tools and techniques used within an industrial environment	
LO2 Analyse cost effective quality control tools		**D2** Develop a process for the application of an extensive range of quality control tools and techniques with emphasis on costing
P3 Analyse the effective use of quality control tools and techniques **P4** Analyse costing techniques used within industry	**M2** Determine with justification the quality control tools and techniques that could be used to improve business performance	
LO3 Determine the role of standards in improving efficiency, meeting customer requirements and opening up new opportunities for trade		**D3** Illustrate a plan for the application of international standards that would improve efficiency, meet customer requirements and open 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	

Pass	Merit	Distinction
LO4 Analyse the importance of Total Quality Management and continuous improvement in manufacturing and service environments		**D4** Analyse how the appropriate application of Total Quality Management and continuous improvement in tools and techniques affect quality performance in the manufacturing and service environments
P6 Analyse 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	

Recommended Resources

Textbooks

OAKLAND, J.S. (2003) *Total Quality Management: Text with Cases*. 3rd Ed. Butterworth-Heinemann.

SLACK, N., CHAMBERS, S. and JOHNSTON, R. (2016) *Operations Management*. 8th Ed. Essex: Pearson Education Limited.

Links

This unit links to the following related units:

Unit 49: Lean Manufacturing

Unit 18: Maintenance Engineering

Unit code K/615/1492

Unit level 4

Credit value 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 explain the importance of compliance with statutory regulations associated with asset maintenance, illustrate maintenance techniques adopted by the industry, work safely whilst performing maintenance tasks in an industrial environment and identify inspection and maintenance techniques.

Learning Outcomes

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

1. Analyse the impact of relevant statutory regulations and organisational safety requirements on the industrial workplace.
2. Differentiate between the merits and use of different types of maintenance strategies in an industrial workplace.
3. Illustrate competence in working safely by correctly identifying the hazards and risks associated with maintenance techniques.
4. Apply effective inspection and maintenance techniques relative to a particular specialisation e.g. mechanical or electrical.

Essential Content

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

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

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

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

LO3 **Illustrate competence in working safely by correctly identifying 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

Development and implementation of safe schemes of work

Lone working

Permit to work (PTW)

Emergency Procedures

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 electrical or mechanical**

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

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

Recording data and maintenance records

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Analyse the impact of relevant statutory regulations and organisational safety requirements in the industrial workplace</td><td rowspan="2">D1 Determine the likely consequences of non-adherence to relevant health and safety legislation by employers and employees
D2 Critically analyse the potential impact of a workplace inspection by a Health and Safety Executive inspector</td></tr>
<tr><td>P1 Describe the key features of health and safety regulations in the workplace
P2 Explain the role of the Health and Safety Executive in health and safety in the workplace</td><td>M1 Analyse the consequences of employers not abiding by health and safety legislation and regulations in the workplace</td></tr>
<tr><td colspan="2">LO2 Differentiate between the merits and use of different types of maintenance strategies in an industrial workplace</td><td rowspan="2">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</td></tr>
<tr><td>P3 Describe the 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</td><td>M2 Explain the importance of carrying out engineering maintenance in an industrial workplace</td></tr>
<tr><td colspan="2">LO3 Illustrate competence in working safely by correctly identifying the hazards and risks associated with maintenance techniques</td><td rowspan="2">D5 Analyse, using actual workplace procedures, the methods used to deal with identified hazards in accordance with statutory legal requirements and workplace policies and recommend improvements</td></tr>
<tr><td>P5 Describe methods used to identify risks and their associated hazards
P6 Carry out a risk assessment on a typical maintenance technique</td><td>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</td></tr>
</table>

Pass	Merit	Distinction
LO4 Apply effective inspection and maintenance techniques relative to a particular specialisation such as mechanical or electrical		**D6** Justify appropriate inspection and maintenance techniques across industrial plant assets
P6 Apply effective inspection and maintenance techniques in an industrial or simulated environment, recording the appropriate sequence of procedures	**M5** Analyse the effectiveness of these inspection and maintenance techniques in plant asset management	

Recommended Resources

Textbooks

MOBLEY, K. (2014) *Maintenance Engineering Handbook.* 8th Ed. McGraw Hill.
RICHARDSON, D.C. (2013) *Plant Equipment and Maintenance Engineering Handbook*. McGraw Hill.

Websites

http://www.soe.org.uk/	*SOE Society of Operations Engineers* IplantE (General Reference)
http://www.imeche.org/	*The Institution of Mechanical Engineers* (General Reference)

Links

This unit links to the following related units:

Unit 30: Operations and Plant Management

Unit 4: Managing a Professional Engineering Project

Unit 19: Electrical and Electronic Principles

Unit code	**M/615/1493**
Unit level	**4**
Credit value	**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:

1. Apply an understanding of fundamental electrical quantities to evaluate circuits with constant voltages and currents.
2. Evaluate circuits with sinusoidal voltages and currents.
3. Describe the basis of semiconductor action, and its application to simple electronic devices.
4. 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 and insulators

Circuit laws:

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

Kirchhoff's and Thevenin's laws; 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

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

Circuits with sinusoidal sources:

Current and voltage in series and parallel RL, RC and RLC circuits. Frequency response and resonance

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

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

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)

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		**D1** Evaluate the operation of a range of circuits with constant sources, using relevant circuit theories.
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	
LO2 Analyse circuits with sinusoidal voltages and currents		**D2** Analyse the operation and behaviour of series and parallel RLC circuits, including resonance and using the principles of circuit theory with sinusoidal sources.
P2 Analyse series RLC circuits, using the principles of circuit theory with sinusoidal sources.	**M2** Analyse series and parallel RLC circuits, using the principles of circuit theory with sinusoidal sources.	
LO3 Describe the basis of semiconductor action, and its application to simple electronic devices		**D3** Analyse the performance of a range of discrete semiconductor devices in terms of simple semiconductor theory, and suggest applications for each.
P3 Describe the behaviour of a p-n junction in terms of semiconductor behaviour **P4** Demonstrate the action of a range of semiconductor devices	**M3** Explain the operation of a range of discrete semiconductor devices in terms of simple semiconductor theory	

Pass	Merit	Distinction
LO4 Explain the difference between digital and analogue electronics, describing simple applications of each		**D4** Evaluate the use of analogue and digital devices and circuits using examples.
P5 Explain the difference between digital and analogue electronics **P6** Explain amplifier characteristics **P7** Explain the operation of a simple circuit made of logic gates	**M4** Explain the benefits of using analogue and digital electronic devices using examples	

Recommended Resources

Textbooks

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

HUGHES, E., HILEY, J., BROWN, K. and MCKENZIE-SMITH, I. (2012) *Electrical and Electronic Technology*. Pearson.

SINGH, K. (2011) *Engineering Mathematics through Applications*. Palgrave.

Pearson BTEC Higher Nationals Study Guide (2011) Custom Publishing. Pearson.

Links

This unit links to the following related units:

Unit 20: Digital Principles

Unit 22: Electronic Circuits and Devices

Unit 52: Further Electrical, Electronic and Digital Principles

Unit 21: Electric Machines

Unit code	**A/615/1495**
Unit level	**4**
Credit value	**15**

Introduction

Electrical machines can be found in manufacturing, transport, consumer appliances and hospitals. People will come across them every day in their home and at work. They convert energy in three ways: transformers which change the voltage level of an alternating current, motors which convert electrical energy to mechanical energy, and generators which convert 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 characteristics and operational parameters of a range of electromagnetic-powered machines that are used in a variety of applications. Among the topics included in this unit are: principles underlying the operation and construction of transformers, induction motors, synchronous machines, electromagnetic transducers and actuators, and generators. Operating characteristics of electrical machines include voltage, current, speed of operation, power rating, electromagnetic interference (EMI) and efficiency.

On successful completion of this unit students will be able to identify the constructional features and applications of transformers; investigate the starting methods and applications of three-phase induction motors and synchronous machines; investigate the types of generator available in the industry by assessing their practical application; and analyse the operating characteristics of electromagnetic transducers and actuators.

Learning Outcomes

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

1. Assess the constructional features and applications of transformers.
2. Analyse the starting methods and applications of three-phase induction motors and synchronous machines.
3. Investigate the types of generator available in industry by assessing their practical applications.
4. Analyse the operating characteristics of electromagnetic transducers and actuators.

Essential Content

LO1 **Assess the constructional features and applications of transformers**

Constructional features:

Construction, application, characteristics and testing of transformer types such as step up, step down and isolating

Shell and core, windings, connections, efficiency, short-circuit and no-load testing and equivalent circuit

LO2 **Analyse the starting methods and applications of the three-phase induction motors and synchronous machines**

Methods and applications:

Construction, application, characteristics and testing of induction and synchronous motors

Types of electric motors and their practical applications

Starting methods

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

Cooling and protection devices

LO3 **Investigate the types of generators available in the industry by assessing their practical application**

Types of generators available:

Construction, application, characteristics and testing of generators

Types (direct current, alternating current and self-excitation)

Practical applications

Generation methods

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

Cooling and protection devices

LO4 **Analyse the operating characteristics 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)

Practical applications

Voltage and current requirements, hysteresis and speed of operation

Torque

Insulation Protection (IP) rating

Contact types

Back Electromotive Force (EMF), EMI and efficiency

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Assess the constructional features and applications of transformers		**D1** Assess the efficiency of a number of available transformers and make a recommendation for an actual operational requirement
P1 Examine the types of transformers available **P2** Discuss suitable applications for available transformers **P3** Discuss the different methods of connections available for three-phase transformers	**M1** Illustrate the operation of the transformer considering the equivalent circuit	
LO2 Analyse the starting methods and applications of the three-phase induction motors and synchronous machines		**D2** Critically evaluate the efficiency of a number of available motors and make a recommendation for a specified operational requirement
P4 Analyse the types of electrical motors available, discussing suitable applications **P5** Analyse the different methods of starting induction motors and synchronous machines	**M2** Justify the selection of a motor for a specific industrial application	
LO3 Investigate the types of generators available in the industry by assessing their practical application		**D3** Assess the efficiency of a number of available generators and make a recommendation for a specified operational requirement
P6 Explain the types and construction of generators **P7** Identify a generator for a specific application considering their characteristics	**M3** Justify the application of a specific type of generator	

Pass	Merit	Distinction
LO4 Analyse the operating characteristics of electromagnetic transducers and actuators		**D4** Analyse the practical application of transducers and actuators in an industrial situation and make recommendations to improve the operating efficiency of the units in use
P8 Analyse the operation, types and uses of electromotive transducers and actuators, examining features that support their suitability for specific applications	**M4** Justify the selection of suitable transducers for specific industrial applications	

Recommended Resources

Textbooks

DE SILVA, C. W. (2015) *Sensors and Actuators: Engineering System Instrumentation*. 2nd Ed. Boca Raton: CRC Press.

HUGHES, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications.* 4th Ed. Boston: Newnes.

Websites

https://ocw.mit.edu	*MIT open courseware* *Electric Machines* (Tutorials)

Links

This unit links to the following related unit:

Unit 43: Further Electrical Machines and Drives

Unit 22: Electronic Circuits and Devices

Unit code	**F/615/1496**
Unit level	**4**
Credit value	**15**

Introduction

Electronics is all around us today, in our homes, the workplace, cars and even on or in our bodies. It's hard to believe that it was only in 1947 that the transistor was developed by American physicists John Bardeen, Walter Brattain, and William Shockley. The invention of the transistor paved the way for cheaper radios, calculators and computers.

This unit introduces students to the use of electronics manufacturers' data to analyse the performance of circuits and devices, the operational characteristics of amplifier circuits, the types and effects of feedback on a circuit performance, and the operation and application of oscillators. They will also be introduced to the application of testing procedures to electronic devices and circuits, 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 and wave shapes and testing procedures.

On successful completion of this unit, a student will be able to determine the operational characteristics of amplifier circuits, investigate the types and effects of feedback on an amplifiers performance, examine the operation and application of oscillators and apply testing procedures to electronic devices and circuits.

Learning Outcomes

By the end of this unit, a student will be able to:

1. Determine the operational characteristics of amplifier circuits.
2. Investigate the types and effects of feedback on an amplifiers performance.
3. Examine the operation and application of oscillators.
4. 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

LO2 **Investigate the types and effects of feedback on amplifier 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

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/noise

Devices to test:

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:

Including; meters, probes and oscilloscopes

Signal generators and signal analysers, logic analysers

Virtual test equipment

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Determine the operational characteristics of amplifier circuits</td><td rowspan="2">D1 Assess the results obtained from the application of practical and virtual tests on amplifier circuits studied</td></tr>
<tr><td>P1 Describe the types of amplifiers available and their applications
P2 Examine the different performance characteristics of types of amplifier</td><td>M1 Explain the results obtained from applying practical tests on an amplifier’s performance</td></tr>
<tr><td colspan="2">LO2 Investigate the types and effects of feedback on an amplifier’s performance</td><td rowspan="2">D2 Evaluate the results of practical and virtual tests to analyse the effect of feedback on an amplifier’s performance</td></tr>
<tr><td>P3 Examine the types of feedback available and their effect on the amplifier’s performance
P4 Describe a circuit which employs negative feedback</td><td>M2 Perform practical tests to show the effect of feedback on an amplifier’s performance</td></tr>
<tr><td colspan="2">LO3 Examine the operation and application of oscillators</td><td rowspan="2">D3 Analyse the results obtained from applying practical and virtual tests on oscillators studied</td></tr>
<tr><td>P5 Examine types of available oscillators and their applications</td><td>M4 Assess the performance characteristics of types of oscillators</td></tr>
<tr><td colspan="2">LO4 Apply testing procedures to electronic devices and circuits</td><td rowspan="2">D4 Analyse and compare the results obtained from applying practical and virtual tests on devices and circuits studied</td></tr>
<tr><td>P6 Select suitable electronic devices and their parent circuits and identify the appropriate manufacturer’s data sheets
P7 Interpret relevant information from manufacturer’s data when testing electronic devices and circuits</td><td>M5 Perform tests on electronic devices and circuits, recording results and recommending appropriate action</td></tr>
</table>

Recommended Resources

Textbooks

HOROWITZ, P. and HILL, W. (2015) *The Art of Electronics* 3rd Ed. Cambridge University Press.

FLOYD, T. L. and BUCHLA D. (2013) *Electronics Fundamentals: Circuits, Devices & Applications*. 8th Ed. Pearson.

BOYLESTAD, R. L. and NASHELSKY, L. (2013) *Electronic Devices and Circuit Theory*. 11th Ed. Pearson.

Websites

www.electronics-tutorials.ws	Electronic Tutorials *Amplifiers* (Tutorials)
www.learnabout-electronics.org	Learn About Electronics *Amplifiers* (Tutorials)
www.learnabout-electronics.org	Learn About Electronics *Oscillators* (Tutorials)
www.electronics-tutorials.ws	Electronic Tutorials *Oscillators* (Tutorials)
http://learn.mikroe.com/	Mikro Elektronika *Introduction to checking components* (E-Book)

Links

This unit links to the following related units:

Unit 44: Machines and Drives

Unit 23: Computer Aided Design and Manufacture (CAD/CAM)

Unit code J/615/1497

Unit level 4

Credit value 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 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 illustrate the key principles of manufacturing using a CAD/CAM system; produce 3D solid models of a component suitable for transfer into a CAM system; use CAM software to generate manufacturing simulations of a component; and design a dimensionally accurate component on a CNC machine using a CAD/CAM system.

Learning Outcomes

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

1. Describe the key principles of manufacturing using a CAD/CAM system.
2. Produce 3D solid models of a component suitable for transfer into a CAM system.
3. Use CAM software to generate manufacturing simulations of a component.
4. Design and produce a dimensionally accurate component on a CNC 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; CAM software e.g. Edgecam, Delcam, GibbsCAM, SolidCAM

Inputs:

CAD model, material specifications, tooling data, spindle speeds and feed rate data calculations

Outputs:

CAM files, program code 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

LO2 **Produce 3D solid models of a component suitable for transfer into a CAM system**

Solid modelling:

Extrude, cut, fillet, chamfer, holes, sweep, revolve, lines, arcs, insert planes, properties of solid models e.g. mass, centre of gravity, surface area

Geometry manipulation:

Mirror, rotate, copy, array, offset

Component drawing:

Set-up template, orthographic and multi-view drawings, sections, scale, dimensions, drawing

Attributes e.g. material, reference points, tolerances, finish

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

LO4 **Design and produce a dimensionally accurate component on a CNC machine using a CAD/CAM system**

CNC machine types:

Machining centres, turning centres, MCUs e.g. Fanuc, Siemens, and Heidenhain

Data transfer:

Structured data between CAD and CAM software e.g. datum position and model orientation; file types e.g. SLDPRT, parasolid, STL, IGES, DXF; transfer to CNC machine e.g. network, USB, Ethernet

Inspection:

Manual inspection e.g. using Vernier gauges, bore micrometres

Automated inspection e.g. co-ordinate measuring machine (CMM), stages of inspection throughout manufacturing process

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the key principles of manufacturing using a CAD/CAM system		**D1** Critically evaluate, using illustrative examples, the impact of different machining conditions and specifications on component manufacturing
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 and tooling available on CNC machines	**M1** Analyse the suitability of different programming methods of CNC machines	
LO2 Produce 3D solid models of a component suitable for transfer into a CAM system		**D2** Critically evaluate the effectiveness of using a CAD/CAM system and solid modelling to manufacture components
P4 Design and produce a CAD solid model of a component to be manufactured on a CNC machine **P5** Design a working drawing of a component containing specific manufacturing detail	**M2** Assess the importance of using different geometry manipulation methods for efficient model production	
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	**M3** Using CAM software, generate cutter tool path simulations	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO4 Design and produce a dimensionally accurate component on a CNC machine using a CAD/CAM system</td><td rowspan="2">D4 Critically analyse, giving illustrative examples, the different methods of data transfer through a CAD/CAM system</td></tr>
<tr><td>P7 Detail a part program for a component using CAM software and transfer the part program to a CNC machine and manufacture a component

P8 Describe the structural elements of a CNC Machining Centre

P9 Review a component manufactured on a CNC machine to verify its accuracy</td><td>M4 Analyse different methods of component inspection used in manufacturing</td></tr>
</table>

Recommended Resources

Textbooks

KUNWOO, L. (2000) *Principles of CAD/CAM/CAE*. Pearson.

McMAHAN, C. and BROWNE, J. (1999) *CADCAM: Principles, Practice and Manufacturing Management*. Prentice Hall.

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 29: Electro, Pneumatic and Hydraulic Systems

Unit code	**L/615/1498**
Unit level	**4**
Credit value	**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 explain applications of hydraulic and pneumatic systems in the production industry, determine the fundamental principles and practical techniques for obtaining solutions to problems, appreciate real-life applications of pneumatic and hydraulic systems, and investigate the importance of structured maintenance techniques.

Learning Outcomes

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

1. Calculate the parameters of pneumatic and hydraulic systems.
2. Identify the notation and symbols of pneumatic and hydraulic components.
3. Examine the applications of pneumatic and hydraulic systems.
4. 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

LO2 **Identify 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

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Calculate the parameters of pneumatic and hydraulic systems		**D1** Produce a presentation analysing fluid viscosity using Stokes' Law and validate how this relates to Navier–Stokes equations
P1 Determine 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	
LO2 Identify the notation and symbols of pneumatic and hydraulic components		**D2** Stating any assumptions, compare the applications of practical hydraulic and pneumatic systems
P3 Identify 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	
LO3 Examine the applications of pneumatic and hydraulic systems		**D3** Evaluate the design modifications that can be introduced to improve the functionality and maintenance of pneumatic and hydraulic systems without creating reliability issues
P6 Investigate and analyse the design and function of a simple hydraulic or pneumatic system in a 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	

Pass	Merit	Distinction
LO4 Investigate the maintenance of pneumatic and hydraulic systems		**D4** Evaluate the importance of maintenance, inspection, testing and fault finding in respect of improved system performance
P8 Recognise system faults and potential hazards in pneumatic and hydraulic systems **P9** Determine regular testing procedures to ensure efficient maintenance of pneumatic and hydraulic systems	**M4** Compare construction and operation of hydraulic and pneumatic systems with regards to legislation and safety issues	

Recommended Resources

Textbooks

PARR, A. (1999) *Hydraulics and Pneumatics: A Technician's Guide*. 2nd Ed. Butterworth-Heinemann.

ROHNER, R. (1995) *Industrial Hydraulic Control*. John Wiley & Sons.

STACEY, C. (1997) *Practical Pneumatics*. Elsevier.

TURNER, I. (1996) *Engineering Applications of Pneumatics and Hydraulics*. Butterworth-Heinemann.

Links

This unit links to the following related units:

Unit 11: Fluid Mechanics

Unit 64: Thermofluids

Unit 30: Operations and Plant Management

Unit code	**R/615/1499**
Unit level	**4**
Credit value	**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 describe 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 these systems.

Learning Outcomes

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

1. Analyse fundamental thermodynamic systems and their properties.
2. Investigate power transmission systems.
3. Determine the parameters of static and dynamic fluid systems.
4. 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) and surroundings

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

Polytropic processes: constant pressure, constant volume, adiabatic and isothermal processes

LO2 **Investigate power transmission systems**

Power transmission:

Flat and v-section belts drives: maximum power and initial tension requirements

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: maximum power transmitted

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

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

Recuperator, regenerator and evaporative heat exchangers

Application of formulae to heat exchangers

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

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Analyse fundamental thermodynamic systems and their properties</td><td rowspan="2">D1 Illustrate the importance of expressions for work done in thermodynamic processes by applying first principles</td></tr>
<tr><td>P1 Examine the operation of thermodynamic systems and their properties

P2 Explain the application of the first law of thermodynamics to appropriate systems

P3 Explain the relationships between system constants for a perfect gas</td><td>M1 Identify the index of compression in polytrophic processes</td></tr>
<tr><td colspan="2">LO2 Investigate power transmission systems</td><td rowspan="2">D2 Compare the ‘constant wear‘ and ‘constant pressure’ theories as applied to friction clutches</td></tr>
<tr><td>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 Determine the power and torque transmitted through gear trains</td><td>M2 Discuss the factors that inform the design of an industrial belt drive system</td></tr>
</table>

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 differences between parallel and counter flow recuperator heat exchangers
P10 Determine 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

Textbooks

DUNN, D. (2001) *Fundamental Engineering Thermodynamics.* Longman.

EASTOP, T.D. and MCCONKEY, A. (1996) *Applied Thermodynamics for Engineering Technologists*. 5th Ed. Prentice Hall.

MASSEY, B.S. and WARD-SMITH, J. (2011) *Mechanics of Fluids*. 9th Ed. Oxford: Spon Press.

Websites

http://www.freestudy.co.uk/	FREESTUDY Tutorials on Engineering (Tutorials)

Links

This unit links to the following related units:

Unit 29: Electro, Pneumatic and Hydraulic Systems

Unit 31: Electrical Systems and Fault Finding

Unit 31: Electrical Systems and Fault Finding

Unit code A/615/1500

Unit level 4

Credit value 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 work place 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:

1. Investigate the constructional features and applications of electrical distribution systems.
2. Examine the types and applications of electrical motors and generators.
3. Analyse the types of lighting circuits available in the industry by assessing their practical application.
4. Explain the operating characteristics of electrical safety components.

Essential Content

LO1 **Investigate the constructional features and applications of electrical distribution systems**

Operating principles:

Three-phase, single-phase distribution methods and connections

Earthing system connections

Transformer constructional features:

Construction, application, characteristics of transformers such as step up/down, isolating, shell and core, windings, connections, efficiency

Electrical circuit symbols and layout diagrams

Fault finding techniques and test equipment:

Input/output, half split

Meters, insulation testers

Typical faults found

LO2 **Examine the types and applications of electrical motors and generators**

Types and applications:

Construction, application, characteristics, and testing

Types of electric motors and generators

Practical applications

Generation methods

Starting methods

Voltages, power, speed, torque, inertia

EMI, efficiency

Cooling and protection devices

LO3 **Analyse the types of lighting circuits available in the industry by assessing their practical application**

Types available and applications:

Construction, application, characteristics and testing of lighting circuits

Types of lights available (high-intensity discharge lamps (HID lamps) such as metal-halide and sodium, fluorescent, light emitting diode (LED) and halogen)

Practical applications

Voltages, energy usage, lumen output, efficiency, recycling

Safety requirements for use in hazardous zones

Heat and protection devices

Lighting design:

Quality of light, control of glare, luminance, internal/external lighting for visual tasks, emergency lighting, use in hazardous environments

LO4 **Explain the operating characteristics of electrical safety components**

Electrical safety standards:

Approved codes of practice

Component types available and applications:

Construction, application, characteristics and testing of: distribution boards, circuit breakers, residual current devices (RCDs), fuses, thermal devices, relays, contactors, switch gear, emergency stop buttons, interlocks, disconnectors, earth connections, Insulation Protection (IP) rating

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the constructional features and applications of electrical distribution systems		**D1** Examine the operation of an electrical distribution system
P1 Describe the features of an electrical distribution system **P2** Review the electrical component symbols used in circuit diagrams **P3** Explain the different methods of single and three-phase connections	**M1** Summarise the methods of safe fault finding on an electrical distribution system	
LO2 Examine the types and applications of electrical motors and generators		**D2** Justify the selection of a motor for a specific industrial application
P4 Explain the types of electrical motors and generators available **P5** Select suitable motors for various industrial applications **P6** Review the different methods of starting induction motors and synchronous machines	**M2** Outline the efficiency of motors and generators	
LO3 Analyse the types of lighting circuits available in the industry by assessing their practical application		**D3** Evaluate the practical application of a specific type of lighting circuit
P7 Examine the types and construction of lighting devices **P8** Explore a suitable lighting type for a specific application, considering its characteristics	**M3** Analyse the efficiency of lighting circuit designs	

Pass	Merit	Distinction
LO4 Explain the operating characteristics of electrical safety components		**D4** Validate the selection of suitable electrical safety devices for a specific industrial application
P9 Describe the operation, types and uses of electrical safety devices **P10** List suitable safety components for a specific application	**M4** Determine the practical application of electrical safety devices in an industrial situation	

Recommended Resources

Textbooks

HUGHES, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications*. 4th Ed. Newnes.

Website

https://ocw.mit.edu/	*MIT open courseware* *Electric Machines* (Tutorials)

Links

This unit links to the following related units:

Unit 19: Electrical and Electronic Principles

Unit 21: Electrical Machines

Unit 22: Electronic Circuits and Devices

Unit 32: CAD for Maintenance Engineers

Unit code F/615/1501

Unit level 4

Credit value 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:

1. Create and modify CAD drawings.
2. Construct, insert and export blocks with textual attributes.
3. Produce complex schematic drawings.
4. Transfer information to external sources.

Essential content

LO1 **Create and modify 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:

Linetypes, circle, text, hatching, dimensioning

Modifying commands:

Copy, rotate, move, erase, scale, chamfer, fillet

Creating and defining text and dimension styles

Creating layers:

Layers/levels, colour

Viewing commands:

Zoom, pan, viewports and layouts

LO2 **Construct, insert and export blocks with 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 **Produce complex schematic drawings**

Create block library and table legend, including symbols and description

Create electrical, electronic, hydraulic and pneumatic schematic drawings

LO4 **Transfer information to external sources**

Electronic transfer of information

Data extraction and data extraction (DXE) files

Extracting data to tables and spreadsheets

Organise and refine the extracted data

Table styles and formatting data extraction tables

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Create and modify CAD drawings		
P1 Identify the range of drawing aids that assist productivity **P2** 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	**D1** Evaluate the advantages of using template files
LO2 Construct, insert and export blocks with textual attributes		
P3 Create ten schematic symbols **P4** Add appropriate attribute data to each of the schematic symbols and convert into blocks	**M2** Identify the advantages of using blocks in a drawing	**D2** Validate how using attributes can improve productivity
LO3 Produce complex schematic drawings		
P5 Produce 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 Extract attribute data to Excel spreadsheets **P8** Explain the advantages of using data extraction (DXE) files	**M4** Appraise the process for extracting drawing data to create a table	**D3** Assess how electronic transfer of information can aid productivity and provide example applications

Recommended Resources

Textbooks

OMURA, G. and BENTON, B.C. (2014) *Mastering AutoCAD 2015 and AutoCAD LT 2015 Essentials*. Autodesk Official Press.

ONSTOTT, S. (2014) *AutoCAD 2015 and AutoCAD LT 2015 Essentials*. Autodesk Official Press.

Websites

https://ocw.mit.edu/	MIT open courseware Electric Machines (Tutorials)

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit: 23 Computer Aided Design and Manufacture (CAD/CAM)

Unit 33: Fundamentals of Nuclear Power Engineering

Unit code K/615/1539

Unit level 4

Credit value 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:

1. Describe the development, current status and future outlook for the nuclear industry in the UK.
2. Apply science and engineering principles to explain the design and operating principles of a nuclear power reactor.
3. Compare and contrast different reactor designs, weighing the advantages and disadvantages of each.
4. 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Describe the development, current status and future outlook for the nuclear industry in the UK</td><td rowspan="2">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</td></tr>
<tr><td>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</td><td>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</td></tr>
<tr><td colspan="2">LO2 Apply science and engineering principles to explain the design and operating principles of a nuclear power reactor</td><td rowspan="2">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</td></tr>
<tr><td>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</td><td>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</td></tr>
<tr><td colspan="2">LO3 Compare and contrast different reactor designs, weighing the advantages and disadvantages of each</td><td rowspan="2">D3 Critically evaluate the concepts being considered for future Generation IV nuclear power reactors, measuring each concept against specific Gen IV design goals</td></tr>
<tr><td>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</td><td>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</td></tr>
</table>

Pass	Merit	Distinction
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		**D4** Evaluate the root causes of three well-documented reactor accidents (case studies) and formulate recommendations for improvements in design and/or operational management
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	

Recommended Resources

Textbooks

HORE-LACY, L. (2012) *Nuclear Energy in the 21st Century: World Nuclear University Primer*. 3rd Ed. London: World Nuclear University Press.

KNIEF, R. A. (1992) *Nuclear Engineering*. Carlsbad: Hemisphere.

LAMARSH, J. R. and BARATTA, A. J. (2001) *Introduction to Nuclear Engineering.* 3rd Ed. London: Pearson.

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 65: Nuclear Reactor Operations

Unit 72: Nuclear Safety Case Development

Unit 34: Research Project

Unit code	**J/615/1502**
Unit type	**Core**
Unit level	**5**
Credit value	**30**

Introduction

Completing a piece of research is an opportunity to showcase your intellect and talents. It integrates knowledge with different skills and abilities that may not have been assessed previously. These may include seeking out and reviewing original research papers, designing your own experimental work, solving problems as they arise, managing your 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, and 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 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 problems, consider multiple perspectives in reaching a balanced and justifiable conclusion and communicate effectively a research project's outcome. They will 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, which are crucial skills for gaining employment and developing academic competence for degree progression.

Learning Outcomes

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

1. Conduct the preliminary stages involved in the creation of an engineering research project.
2. 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.
3. Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering context.
4. Explore the communication approach used for the preparation and presentation of the research project's outcomes.

Essential Content

LO1 **Conduct the preliminary stages involved in the creation of an engineering research project**

Setting up the research preliminaries:

Project proposal

Developing a research question(s)

Selection of project approach

Identification of project supervisor

Estimation of resource requirements, including possible sources of funding

Identification of project key objectives, goals and rationale

Development of project specification

LO2 **Examine the analytical strategies and techniques used to work on the literature review and data analysis and collection stages of the research project**

Investigative skills and project strategies:

Selecting the method(s) of collecting data

Data analysis and interpreting findings

Literature review

Engaging with technical literature

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 context**

Research purpose:

Detailed statement of project aims

Relevance of the research

Benefits and beneficiaries of the research

LO4 **Explore the communication approach used for the preparation and presentation of the research project's outcomes**

Reporting the research:

Project written presentation

Preparation of a final project report

Writing research report

Project oral presentation such as using short presentation to discuss the work and conclusions

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Conduct the preliminary stages involved in the creation of an engineering research project		**D1** Produce a comprehensive project proposal that evaluates and justifies the rationale for the research
P1 Produce a research project proposal that clearly defines a research question or hypothesis **P2** Discuss the key project objectives, the resulting goals and rationale	**M1** Analyse the project specification and identify any project risks	
LO2 Examine the analytical strategies and techniques used to work on the literature review and data analysis and collection stages of the research project		**D2** Critically analyse literature sources used, data analysis conducted and strategies to deal with challenges
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	
LO3 Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering context		**D3** Critically evaluate how the research experience enhances personal or group performance within an engineering 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	

Pass	Merit	Distinction
LO4 Explore the communications approach used for the preparation and presentation of the research project's outcomes		**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
P6 Explore the different types of communications approaches that can be used to present the research outcomes **P7** Communicate research outcomes in an appropriate manner for the intended audience	**M5** Evaluate how the communication approach meets research project outcomes and objectives	

Recommended Resources

Textbooks

LEONG, E. C., LEE-HSIA, C. H. and WEE ONG, K. K. (2015) *Guide to Research Projects for Engineering Students - Planning, Writing and Presenting*. Oakville: Apple Academic Press Inc.

OBERLENDER, G. D. (2014) *Project Management for Engineering and Construction*. 3rd Ed. New York: McGraw-Hill Education.

Websites

https://www.apm.org.uk/	Association for Project Management (General Reference)

Links

This unit links to the following related unit:

Unit 5: Project

Unit 35: Professional Engineering Management

Unit code	**L/615/1503**
Unit type	**Core**
Unit level	**5**
Credit value	**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 on the knowledge gained in Unit 4. It provides students with the professional standards for engineers and guides 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, 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 personal commitment to professional standards and obligations to society, the engineering profession and the environment.

This unit is assessed by a Pearson-set assignment. 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:

1. Evaluate the risk evaluation theories and practices associated with the management of projects for the production of current and developing technology.
2. Produce an engineering services delivery plan that meets the requirements of a sector-specific organisation.
3. Develop effective leadership skills and individual and group communication skills.
4. Develop personal commitment to professional standards and obligations to society, the engineering profession and the environment.

Essential Content

LO1 **Evaluate the risk evaluation theories and practices associated with the management of projects for the production of current and developing technology**

The engineering business environment:

Organisational structures and functional elements

Strategic planning and deployment

Engineering strategy and services delivery planning

The role of sustainability

Total quality management

Logistics and supply chain management

New product development strategies

Legal obligations and corporate responsibility

Engineering relationships:

The relationship between engineering and financial management, marketing, purchasing, quality assurance and public relations

LO2 **Produce an engineering services delivery plan that meets the requirements of a sector-specific organisation**

Engineering management tools:

Problem analysis and decision making, risk management, change management, performance management, product and process improvement, project management and earned value analysis

LO3 **Develop effective leadership, individual and group communication skills**

Managing people:

Describe the most effective leadership styles

Techniques for effectively managing teams

Steps to follow for delivering effective presentations

Meeting management skills

Communication and listening skills

Negotiating skills

Human error evaluation

Coaching and mentoring

LO4 **Develop 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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the risk evaluation theories and practices associated with the management of projects for the production of current and developing technology		**D1** Specify and analyse the challenges encountered when meeting the requirements for successfully managing engineering activities and make justified recommendations to overcome these challenges
P1 Evaluate the risk evaluation theories and practices associated with the management of engineering projects **P2** Assess elements and issues that impact the successful management of engineering activities	**M1** Critically evaluate the main elements and issues that impact the successful management of engineering activities	
LO2 Produce an engineering services delivery plan that meets the requirements of a sector-specific organisation		**D2** Critically evaluate contingencies that might prevent the delivery plan meeting the requirements of a sector-specific organisation
P3 Develop an engineering services delivery plan applying the appropriate sector-specific requirements **P4** Determine the engineering management tools needed for designing an engineering services delivery plan	**M2** Evaluate how each step of the delivery plan developed meets the requirements of a sector-specific organisation	
LO3 Develop effective leadership, individual and group communication skills		**D3** Critically evaluate effective ways for the coaching and mentoring of disillusioned colleagues or of a poorly performing team
P5 Describe the steps for effective persuasion and negotiation **P6** Explain the steps for managing effective group meetings **P7** Outline the steps to follow to deliver an effective presentation	**M3** Evaluate leadership styles and effective communication skills using specific examples in an organisational context	

Pass	Merit	Distinction
LO4 Develop personal commitment to professional standards and obligations to society, the engineering profession and the environment		**D4** Evaluate and provide justifications for why it is necessary to be active and up to date with the engineering profession's new developments and discoveries
P8 Discuss the context of social responsibility for scientists and engineers **P9** Explore the ways in which an engineer can engage in continuing professional development	**M4** Summarise the engineering profession ethical standards and patterns of behaviour	

Recommended Resources

Textbooks

BURNS, B. (2014) *Managing Change*. 6th Ed. London: Pearson.

DEARDEN, H. (2013) *Professional Engineering Practice: Reflections on the Role of the Professional Engineer*. North Charleston: CreateSpace Independent Publishing Platform.

KARTEN, N. (2010) *Presentation Skills for Technical Professionals*. Ely: IT Governance Ltd.

LOCK, D. (2013) *Project Management*. 10th Ed. London: Routledge.

Websites

http://www.engc.org.uk/	Engineering Council UK-SPEC UK Standard for Professional Engineering Competence (E-Books)
http://www.ewb-uk.org/	Engineering without Borders (General Reference)

Links

This unit links to the following related unit:

Unit 4: Managing a Professional Engineering Project

Unit 36: Advanced Mechanical Principles

Unit code R/615/1504

Unit level 5

Credit value 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 the Unit 9 Mechanical Principles unit. It will provide students with advance knowledge of the mechanical theories associated with engineering applications.

Topics included in this unit are: 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 have more advanced knowledge of mechanical principles to determine the behavioural characteristics of materials subjected to complex loading, assess the strength of loaded beams and pressurised vessels, determine specifications of power transmission system elements and examine operational constraints of dynamic rotating systems.

Learning Outcomes

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

1. Determine the behavioural characteristics of materials subjected to complex loading.
2. Assess the strength of loaded beams and pressurised vessels.
3. Analyse the specifications of power transmission system elements.
4. Examine operational constraints of dynamic rotating 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

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

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

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 rotating systems**

Operational constraints:

Design of both radial plate and cylindrical cams to meet operating specifications

Operating principles of flywheels to store mechanical energy

Balancing of rotating mass systems

The effects of coupling on freely rotating systems

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Determine the behavioural characteristics of materials subjected to complex loading		**D1** Critique 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	
LO2 Assess the strength of loaded beams and pressurised vessels		**D2** Critique and justify your choice of a suitable size universal beam using appropriate computer software to model the application by explaining any assumptions that could affect the selection
P4 Evaluate the variation of slope and deflection along a simply supported beam **P5** Determine the principal stresses that occur in a thin-walled cylindrical pressure vessel and a pressurised thick-walled cylinder	**M2** Review a suitable size universal beam from appropriate data tables which conforms to given design specifications for slope and deflection	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Analyse the specifications of power transmission system elements</td><td rowspan="2">D3 Evaluate the conditions needed for an epicyclic gear train to become a differential, and show how a differential works in this application</td></tr>
<tr><td>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</td><td>M3 Critically analyse both the uniform wear and uniform pressure theories of friction clutches for their effectiveness in theoretical calculations</td></tr>
<tr><td colspan="2">LO4 Examine operational constraints of dynamic rotating systems</td><td rowspan="2">D4 Critically evaluate and justify the different choices of cam follower that could be selected to achieve a specified motion, explaining the advantages and disadvantages of each application</td></tr>
<tr><td>P9 Explore the profiles of both radial plate and cylindrical cams that will achieve a specified motion

P10 Show 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 rotating system</td><td>M4 Evaluate the effects of misalignment of shafts and the measures that are taken to prevent problems from occurring</td></tr>
</table>

Recommended Resources

Textbooks

BIRD, J. and ROSS, C. (2014) *Mechanical Engineering Principles*. 3rd Ed. London: Routledge.

KHURMI, R. S. and GUPTA, J. K. (2005) *Textbook of Machine Design*. New Delhi: S. Chand Publishing.

TOOLEY, M. and DINGLE, L. (2012) *Engineering Science: For Foundation Degree and Higher National*. London: Routledge.

Websites

https://www.khanacademy.org/	Khan Academy Physics (Tutorials)

Links

This unit links to the following related unit:

Unit 8: Mechanical Principles

Unit 37: Virtual Engineering

Unit code Y/615/1505

Unit level 5

Credit value 15

Introduction

Increasingly, the work of an engineer 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 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 multidimensional problems, meshing and boundary conditions and the finite volume method.

On successful completion of this unit, students will be able to consider how to perform computational fluid dynamics Computational Fluid Dynamics (CFD) simulations, develop finite element product and system models, explain the identification of faults in the application of simulation techniques and discuss the modelling method and data accuracy.

Learning Outcomes

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

1. Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering.
2. Analyse finite element product and system models to find and solve potential structural or performance issues.
3. Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting.
4. Determine 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

Design tools:

2D and 3D CAD

Solid modelling

File types, export and compatibility

Interpretation and presentation of results through a series of guided exercises:

Results obtained, comparison of data, benefits and limitations

Generalisation of provided information, recommendations on current and future applications

LO2 **Analyse finite element product and system models to find and solve potential structural or performance issues**

Finite element formulation:

One-dimensional problems

Multidimensional problems

Beams

Finite element method:

Define the problem; simplify an engineering problem into a problem that can be solved using FEA

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:

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 using graphical and numerical tools to suggest and make revisions to the models

LO4 **Determine 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 through a series of guided exercises

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering</td><td rowspan="2">D1 Critically evaluate and provide supported recommendations for the application of computer-based models to an industrial environment that would improve efficiency and problem solving</td></tr>
<tr><td>P1 Discuss the benefits and pitfalls of computer-based models used within an industrial environment to solve problems in engineering</td><td>M1 Evaluate the capabilities and limitations of computer-based models

M2 Evaluate the processes and applications used in solving problems in engineering</td></tr>
<tr><td colspan="2">LO2 Analyse finite element product and system models to find and solve potential structural or performance issues</td><td rowspan="2">D2 For a range of practical examples, provide supported and justified recommendations for recognising and solving potential structural or performance-based issues, using finite element product and systems models</td></tr>
<tr><td>P2 Analyse the role of finite element analysis in modelling products and systems

P3 Review a range of practical examples to solve potential structural or performance-based issues using finite element product and systems models</td><td>M3 Critically analyse the finite element product and systems models that help to find and solve potential performance or structural issues for a range of practical examples</td></tr>
<tr><td colspan="2">LO3 Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting</td><td rowspan="2">D3 Provide supported and appropriate recommendations for improving efficiency and the generation of suitable meshes for CFD simulations</td></tr>
<tr><td>P4 Demonstrate the importance of CFD simulations applied to evaluate pressure and velocity distributions in the engineering setting</td><td>M4 Evaluate the application and limitations of CFD in an engineering context</td></tr>
</table>

Pass	Merit	Distinction
P5 Complete CFD simulation to evaluate pressure and velocity distributions within an engineering setting		
LO4 Determine faults in the application of simulation techniques to evaluate the modelling method and data accuracy		**D4** Critically evaluate the appropriate application of simulation techniques that can support decision making
P6 Determine the faults in the application of simulation techniques **P7** Discuss and evaluate the modelling method and data accuracy	**M5** Extract relevant information from simulation **M6** Trace potential faults in the application of simulation techniques **M7** Critically review results through a series of guided exercises and recommendations	

Recommended Resources

Textbooks

DATE, A. W. (2005) *Introduction to Computational Fluid Dynamics*. Cambridge: Cambridge University Press.

FISH, J. and BELYTSCHKO, T. (2007) *A First Course in Finite Elements*. Boston: Wiley.

TREVOR, H. and BECKER, A. A. (2013) *Finite Element Analysis for Engineers: A Primer*. Hamilton: National Agency for Finite Element Methods & Standards.

Websites

www.tandfonline.com	Taylor & Francis Online *International Journal of Computational* (Journal)
http://www.inderscience.com/	Inder Science Publishers *Progress in Computational Fluid Dynamics, An International Journal* (Journal)
https://www.nafems.org/	NAFEMS *International Journal of CFD Case Studies* (Journal)

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 50: Advanced Manufacturing Technology

Unit 38: Further Thermodynamics

Unit code	**D/615/1506**
Unit level	**5**
Credit value	**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 twenty-first century cannot be underestimated.

The aim of this unit is to build on the techniques explored in Unit 14: Fundamentals of Thermodynamics and Heat Engines. It develops further the student's 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 determine the performance and operation of heat pumps and refrigeration systems, review the applications and efficiency of industrial compressors, use charts and/or tables to determine steam plant parameters and characteristics, and describe the operation of gas turbines and assess their efficiency.

Learning Outcomes

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

1. Evaluate the performance and operation of heat pumps and refrigeration systems.
2. Review the applications and efficiency of industrial compressors.
3. Determine steam plant parameters and characteristics using charts and/or tables.
4. 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

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

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, reheat and regeneration

Combined heat and power plants

Self-starting and burner ignition continuation

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the performance and operation of heat pumps and refrigeration systems		**D1** Conduct a cost-benefit analysis on the installation of a ground source heat pump on a smallholding to make valid recommendations for improvements
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	
LO2 Review the applications and efficiency of industrial compressors		**D2** Critically evaluate the volumetric efficiency formula for a reciprocating compressor
P3 Assess the different types of industrial compressor 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	
LO3 Determine steam plant parameters and characteristics, using charts and/or tables		**D3** Critically evaluate the pragmatic modifications made to the basic Rankine cycle to improve the overall efficiency of steam generation power plants
P6 Discuss the need for superheated steam in power-generating plants **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	

Pass	Merit	Distinction
LO4 Examine the operation of gas turbines and assess their efficiency		**D4** Critically analyse the practical solutions manufacturers offer to overcome problematic areas in gas turbines such as burner ignition continuation and self-starting capabilities
P8 Investigate the principles of operation of a gas turbine plant **P9** Assess the efficiency of a gas turbine system	**M5** Compare and evaluate the actual plant and theoretical efficiencies in a single-shaft gas turbine system, accounting for any discrepancies found	

Recommended Resources

Textbooks

EASTOP, T. D. and MCCONKEY, A. (1996) *Applied Thermodynamics for Engineering Technologists*. 5th Ed. Upper Saddle River: Prentice-Hall.

EASTOP, T. D. and MCCONKEY, A. (1996) *Applied Thermodynamics for Engineering Technologists Student Solutions Manual*. 5th Ed. Upper Saddle River: Prentice-Hall.

RAYNER, J. (2008) *Basic Engineering Thermodynamics*. 5th Ed. London: Pearson.

Websites

http://www.freestudy.co.uk/	Free Study (Tutorials)

Links

This unit links to the following related unit:

Unit 13: Fundamentals of Thermodynamics and Heat Engines

Unit 39: Further Mathematics

Unit code H/615/1507

Unit level 5

Credit value 15

Introduction

The understanding of more advanced mathematics is important within an engineering 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 2: Engineering Maths*.

The unit will prepare students to analyse and model engineering 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 context. Finally, students will expand their knowledge of calculus to discover how to model and solve engineering 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 applications using matrix methods, approximate solutions of contextualised examples with graphical and numerical methods, and review models of engineering systems using ordinary differential equations.

Learning Outcomes

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

1. Use applications of number theory in practical engineering situations.
2. Solve systems of linear equations relevant to engineering applications using matrix methods.
3. Approximate solutions of contextualised examples with graphical and numerical methods.
4. Review models of engineering systems using ordinary differential equations.

Essential Content

LO1 **Use applications of number theory in practical engineering 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

Complex number applications e.g. electric circuit analysis, information and energy control systems

LO2 **Solve systems of linear equations relevant to engineering 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

Gaussian elimination to solve systems of linear equations (up t 3x3)

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

LO4 **Review models of engineering systems using ordinary differential equations**

Differential equations:

Formation and solutions of first-order differential equations

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 such as electric circuit theory, load frequency control, harmonic vibrations of beams, and engine governors

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Use applications of number theory in practical engineering situations		**D1** Test the correctness of a trigonometric identity using de Moivre's Theorem
P1 Apply addition and multiplication methods to numbers that are expressed in different base systems **P2** Solve engineering problems using complex number theory **P3** Perform arithmetic operations using the polar and exponential form of complex numbers	**M1** Solve problems using de Moivre's Theorem	
LO2 Solve systems of linear equations relevant to engineering applications using matrix methods		**D2** Validate solutions for the given engineering linear equations using appropriate computer software
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	

Pass	Merit	Distinction
LO3 Approximate solutions of contextualised examples with graphical and numerical methods		**D3** Critically evaluate the use of numerical estimation methods, commenting on their applicability and the accuracy of the methods
P6 Estimate 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	
LO4 Review models of engineering systems using ordinary differential equations		**D4** Critically evaluate first and second-order differential equations when generating the solutions to engineering situations using models of engineering systems
P9 Formulate and solve first order differential equations related to engineering systems **P10** Formulate and solve second order homogeneous and non-homogeneous differential equations related to engineering 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 problems	

Recommended Resources

Textbooks

BIRD, J. (2014) *Higher Engineering Mathematics*. 7th Ed. London: Routledge.

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

Communications on Pure and Applied Mathematics. Wiley.

Journal of Engineering Mathematics. Springer.

Journal of Mathematical Physics. American Institute of Physics.

Websites

http://www.mathcentre.ac.uk/	Maths Centre (Tutorials)
http://www.mathtutor.ac.uk/	Maths Tutor (Tutorials)

Links

This unit links to the following related unit:

Unit 2: Engineering Maths

Unit 40: Commercial Programming Software

Unit code K/615/1508

Unit level 5

Credit value 15

Introduction

The use of computer-aided design 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 while 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 students will be able to:

1. Research a range of software application tools to determine how they can support electronic engineering functions effectively.
2. Explore 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.
3. Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software.
4. 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 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

Motor, relay and sound outputs

Simulation and debugging

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		**D1** Evaluate the functions and benefits of a range of commercial software used in developing electrical engineering
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	
LO2 Explore 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		**D2** Critically evaluate the functionality of simulation in comparison to real components using a complex PCB layout
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	
LO3 Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software		**D3** Critically evaluate the functionality of simulation by noting variations between testing and simulation
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	

Pass	Merit	Distinction
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		**D4** Critically analyse current and emerging applications of commercial software with clear application to industry examples identifying trends, and recognising technical and economic factors which influence developments
P7 Evaluate an electronics software application and its ability to replicate the real world supported by industry-specific examples 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 illustrating the resource-savings implications this has	

Recommended Resources

Textbooks

BLUM, J. (2013) *Exploring Arduino*. Boston: Wiley.

PETRUZZELLIS, T. (2005) *Build Your Own Electronics Workshop.* New York: McGraw-Hill.

RICHARDSON, M. and WALLACE, S. (2013) *Getting Started with Raspberry Pi*. 1st Ed. San Francisco: Maker Media Inc.

ROBBINS, A. and MILLER, W. C. (2013) *Circuit Analysis: Theory and Practice*. 5th Ed. Clifton Park: 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 37: Virtual Engineering

Unit 41: Distributed Control Systems

Unit 23: Computer-Aided Design and Manufacture (CAD/CAM)

Unit 41: Distributed Control Systems

Unit code M/615/1509

Unit level 5

Credit value 15

Introduction

With increased complexity and greater emphasis on cost control and environmental issues, the efficient control of manufacture and processing plants 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 DCS 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 on modern control processes, explain the basic concepts, architecture, operation and communication of distributed control systems, identify appropriate techniques to specify and implement a simple distributed control system, 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:

1. Explore the impact of automated systems in modern control processes.
2. Evaluate the basic concepts, architecture, operation and communication of distributed control systems.
3. Suggest appropriate techniques to specify and implement a simple distributed control system.
4. 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 (DCS)**

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

Pass	Merit	Distinction
LO1 Explore the impact of automated systems in modern control processes		**D1** Critically evaluate and justify the selection of the control strategies and their function against the specifications of a DCS
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	**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	
LO2 Evaluate the basic concepts, architecture, operation and communication of distributed control systems		**D2** Critically evaluate the performance of the operator interface in a distributed control system and its associated hardware
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	**M3** Critique the input–output interface, field bus 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	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Suggest appropriate techniques to specify and implement a simple distributed control system (DCS)</td><td rowspan="2">D3 Analyse the interfacing, structure and performance of a good alarm system</td></tr>
<tr><td>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 pre-defined parameters</td><td>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</td></tr>
<tr><td colspan="2">LO4 Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system</td><td rowspan="2">D4 Analyse and justify the choice of hardware, software and communication systems and their strategy in terms of architecture, system requirements, system integration and toolkits available</td></tr>
<tr><td>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</td><td>M7 Show how the configuration control procedures ensure data integrity

M8 Explore the requirements for in-built diagnostics and maintenance diagnostic routines</td></tr>
</table>

Recommended Resources

Textbooks

BAILEY, D. and WRIGHT, E. (2003) *Practical SCADA for Industry*. Boston: Newnes.

BOYER, S. (2004) *SCADA – Supervisory Control and Data Acquisition System*. 3rd Ed. Research Triangle Park: The International Society of Automation.

SHARMA, K. (2011) *Overview of Industrial Process Automation*. Boston: Elsevier.

Links

This unit links to the following related units:

Unit 40: Commercial Programming Software

Unit 42: Further Programmable Logic Controllers (PLCs)

Unit code	**H/615/1510**
Unit level	**5**
Credit value	**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:

1. Discuss the selection of a specific PLC for a given industrial application.
2. Evaluate how PLCs exchange information and process signals with other devices.
3. Design a PLC programme to solve an industrial process problem for a given application.
4. 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 systems (SCADA) 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 for 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 (PLDs)

Peripheral Interface Controllers (PICs)

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 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 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 program used to solve an industrial application problem
P5 Design a PLC programme to solve an industrial application problem **P6** Demonstrate the use of PLC programing 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	

Pass	Merit	Distinction
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

Textbooks

BOLTON, W. (2015) *Programmable Logic Controllers*. 5th Ed. Boston: Newnes.

KAMEL, K. and KAMEL, E. (2013) *Programmable Logic Controllers: Industrial Control*. New York: McGraw-Hill Education.

MORTON, J. (2005) *The PIC Microcontroller: Your Personal Introductory Course*. 3rd Ed. Boston: Newnes.

PÉREZ ADROVER, E. (2012) *Introduction to PLCs: A Beginner's Guide to Programmable Logic Controllers*. Self-published.

Websites

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 40: Commercial Programming Software

Unit 15: Automation, Robotics and Programmable Logic Controllers

Unit 6: Mechatronics

Unit 43: Further Electrical Machines and Drives

Unit code	**K/615/1511**
Unit level	**5**
Credit value	**15**

Introduction

Electric machines are the most common devices used to perform the actuator function in an industrial control loop. They 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, their characteristics, starting and braking, loading conditions, ratings, and their control.

On successful completion of this unit students will be able to explain the operation of different motors used in industry, describe the different types of industrial drives used in various disciplines, assess the importance of electrical machines and their drives for a given industrial application, analyse their performances, and suggest appropriate solutions using a variety of possible methods.

Learning Outcomes

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

1. Explore the principles of operation and characteristics of electrical machines and their industrial applications.
2. Illustrate the fundamentals of power electronics converters used in power-processing units for electric drives.
3. Demonstrate the fundamentals of DC drives and their industrial applications.
4. Demonstrate the fundamentals of AC drives and their industrial applications.

Essential Content

LO1 **Explore 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:

Introduction to 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

Simulation using Matlab/Simulink or similar commercially available software

LO2 **Examine the fundamentals of power electronics converters used in power-processing units for electric drives**

Fundamentals of power electronics converters used in power-processing units for electric drives:

Concepts of electrical drives and their classification

DC to DC converters (choppers), 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 **Demonstrate the fundamentals of DC drives and their industrial applications**

Fundamentals of DC drives and their industrial applications:

Introduction to DC drives and their application to emerging areas such as smart grid and renewable energy sources

Operating modes of DC drives: single-phase drives, three-phase drives, chopper drives, two/four-quadrant operation drives

Application: closed-loop control of DC drives

Simulation using Matlab/Simulink or similar commercially available software

LO4 **Demonstrate the fundamentals of AC drives and their industrial applications**

Fundamentals of AC drives and their industrial applications:

Introduction to AC drives and their industrial application such as smart grid and renewable energy sources

Induction motor drives: voltage controls, frequency controls, current controls, voltage, current and frequency control and closed-loop control induction motor

Synchronous motor drives: frequency control and closed-loop control of synchronous motor drives

Simulation using Matlab/Simulink or similar commercially available software

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explore the principles of operation and the characteristics of electrical machines and their industrial applications</td><td rowspan="2">D1 Critically evaluate the performance of a given electrical machine using Matlab/Simulink or similar commercially available software to corroborate its performance or otherwise</td></tr>
<tr><td>P1 Discuss the different types of electrical machines and cite their industrial applications
P2 Illustrate the principle of operation of electrical machines with the aid of circuit diagrams and waveforms
P3 Investigate the construction, operation and characteristics of a given electrical machine</td><td>M1 Use Matlab/Simulink or similar commercially available for modelling and simulation of a given electrical machine
M2 Analyse the characteristics of a given electrical machine from its equivalent circuits</td></tr>
<tr><td colspan="2">LO2 Examine the fundamentals of power electronics converters used in power-processing units for electric drives</td><td rowspan="2">D2 Critically evaluate the performance of a given converter using Matlab/Simulink software to corroborate its performance or otherwise</td></tr>
<tr><td>P4 Illustrate with the aid of circuit diagrams and waveforms the operation of a given uncontrolled or controlled converter (half wave/full wave/three phase)
P5 Illustrate with aid of circuit diagrams and waveforms the impact of resistive and inductive loads on the converter's input and output characteristics
P6 Investigate the importance of input and output filters in a given converter</td><td>M3 Show how Matlab/Simulink or similar commercially available software may be used for the modelling and simulation of a given converter
M4 Evaluate the key performance characteristics of a given converter</td></tr>
</table>

Pass	Merit	Distinction
LO3 Demonstrate the fundamentals of DC drives and their industrial applications		**D3** Analyse the impact of DC drives on the operation and performance of an industrial control system
P7 Discuss the operating modes of DC drives and control parameters **P8** Explain the importance of DC drives in industrial applications **P9** Discuss the principle operations of single/three-phase choppers with the aid of circuit diagrams and waveforms **P10** Illustrate the implementation of closed-loop control of DC drives with the aid of circuit diagrams and waveforms	**M5** Develop an open-loop block diagram of a DC motor and derive the relationship between the input and output of the systems **M6** Evaluate how DC drive circuits are used to control the speed of DC motors	
LO4 Demonstrate the fundamentals of AC drives and their industrial applications		**D4** Analyse the impact of AC drives on the operation and performance of an industrial control system
P11 Illustrate the operating modes of AC drives, their control parameters and their importance in industrial applications **P12** Illustrate the principles of operations of single/three-phase AC drives with the aid of circuit diagrams and waveforms **P13** Review the implementation of closed-loop control of AC drives with the aid of circuit diagrams and waveforms	**M7** Develop an open-loop block diagram of an induction motor and derive the relationship between the input and output of the systems **M8** Evaluate how AC drive circuits are used to control the speed of induction and synchronous motors	

Recommended Resources

Textbooks

HUGHES, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications*. 4th Ed. Boston: Newnes.

RASHID, M. H. (2001) *Power Electronics Handbooks*. 1st Ed. Cambridge: Academic Press.

RASHID, M. H. (2004) *Circuits, Devices and Applications.* 3rd Ed. Upper Saddle River: Prentice-Hall.

Links

This unit links to the following related unit:

Unit 21: Electric Machines

Unit 44: Industrial Power, Electronics and Storage

Unit code M/615/1512

Unit level 5

Credit value 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, heating/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 demands of the future.

The unit will also explore the potential impacts of climate change and why more and different forms of sustainable energy sources, as well as energy efficiency measures, are required.

By the end of this unit students will be able to examine the technological concepts behind providing a sustainable electrical energy supply for the future. They will also be able to describe how the fundamental technical and economic processes and drivers at play in the electrical power industry affect the selection and use of energy sources.

Learning Outcomes

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

1. Evaluate energy demand to determine the technology and methods of energy production.
2. Discuss current energy efficiency measures, technologies and policies specific to the building and transportation sectors.
3. Analyse the control techniques of power electronics for renewable energy systems.
4. 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 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

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

Energy and electric vehicles:

Electrical vehicle configurations, requirements, and circuit topology

Electric and plug-in hybrid vehicles

Policies, measures and technologies to support more sustainable transportation

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 electronics 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

Stand-alone and grid-connected renewable energy systems

Introduction to smart grid, features, functions, architectures, and distributed generation

Grid-interactive systems, grid-tied systems, inverters and application of devices

Smart homes, power management and smart grid, intelligent 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

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Evaluate the energy demand to determine the technology and methods of energy production</td><td rowspan="2">D1 Critically evaluate the performance of a renewable energy system and the technologies used in energy efficiency improvement</td></tr>
<tr><td>P1 Investigate current energy sources, demand and their impact on the environment

P2 Examine the benefits and effectiveness of renewable energy sources

P3 Explore renewable energy technologies and their costs</td><td>M1 Determine the use of energy sources to assess their global impact on energy demand

M2 Evaluate the effectiveness and drawbacks of renewable energy systems for short and long-term energy demands</td></tr>
<tr><td colspan="2">LO2 Explore current energy efficiency measures, technologies and policies specific to the building and transportation sectors</td><td rowspan="2">D2 Analyse the dynamic performance of a power electronic converter for a given renewable energy source and calculate the energy and cost savings against conventional power sources – include a consideration for development and installation costs</td></tr>
<tr><td>P4 Discuss current energy efficiency measures

P5 Determine the main factors that impact on energy use and efficiency in a building

P6 Discuss the technologies that could be used to support more sustainable transport</td><td>M3 Apply modelling of energy management in a building or electric vehicle using Matlab/Simulink (or equivalent)

M4 Evaluate the selection of suitable technologies to improve energy efficiency in a building or electric vehicle</td></tr>
</table>

Pass	Merit	Distinction
LO3 Analyse the control techniques of power electronics for renewable energy systems		**D3** Critically evaluate the dynamic performance of integrating renewable energy sources to the smart grid network using standard industrial-based software, such as Matlab/Simulink software (or equivalent)
P7 Analyse the applications of power electronics in renewable energy applications **P8** Determine the industrial application of power electronic converters **P9** Analyse the power electronic converter topologies and their principles of operation	**M5** Simulate a simple power converter for a typical renewable energy system using a standard software package, such as Matlab/Simulink (or equivalent) **M6** Critically analyse the use of the power converter selected above for a renewable energy application	
LO4 Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid		**D4** Critically analyse the impact of renewable energy sources and their integration to the grid using standard industrial-based software, such as Matlab/Simulink (or equivalent)
P10 Investigate the safe operation of a smart power system **P11** Investigate the principle of operation of stand-alone and grid-connected renewable energy systems **P12** Discuss the features of a smart grid network **P13** Determine the importance of power electronics in smart grid and energy storage	**M7** Analyse how power electronic converters are used in smart grid networks **M8** Evaluate the issues associated with integrating renewable energy sources to the grid	

Recommended Resources

Textbooks

ABU-RUB, H., MALINOWSKI, M. and AL-HADDAD, K. (2014) *Power Electronics for Renewable Energy systems, Transportation and Industrial Applications*. Boston: John Wiley and Sons Ltd.

EKANAYAKE, J. and JENKINS, N. (2012) *Smart Grid Technology and Applications*. Boston: John Wiley & Sons Ltd.

RASHID, M. H. (2013) *Power Electronics – Circuits, Devices and Applications*. 4th Ed. London: Pearson.

TWIDELL, J. and WEIR, T. (2006) *Renewable Energy Resources*. 2nd Ed. London: Taylor and Francis.

Links

This unit links to the following related units:

Unit 51: Sustainability

Unit 53: Utilisation of Electrical Power

Unit 45: Industrial Systems

Unit code T/615/1513

Unit level 5

Credit value 15

Introduction

The speed and efficiency of many industrial processes is largely due to the control systems selected for their 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 industrial situations. An essential requirement here is the engineer’s ability to use 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 the speed or torque of a motor or responding to changes of circumstances in a process.

On successful completion of this unit students will be able to describe system elements and consider their overall characteristics. This provides an opportunity for analytically assessing the accuracy and repeatability of electronic instruments.

Learning Outcomes

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

1. Describe the main elements of an electronically controlled industrial system.
2. Identify and specify the interface requirements between electronic, electrical and mechanical transducers and controllers.
3. Apply practical and computer-based methods to design and test a measurement system.
4. Apply appropriate analytical techniques to predict the performance of a given system.

Essential Content

LO1 **Describe 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

Describe the system elements and the principles and applications of important and representative AC and DC motors

LO2 **Identify 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

Interfacing between electrical, electronic and mechanical transducers

Practical measurement using sensors and transducers, process actuators for temperature and pressure control

LO3 **Apply 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 errors and uncertainty in industrial systems

Use of computer packages in measurement and control, dealing with uncertainty and errors in systems

LO4 **Apply appropriate analytical techniques to predict the performance of a given system**

Apply analytical and computing techniques to predict the performance of an existing system

Consideration of current trends in technology including the future of industrial systems, the impact of digital developments, the increase of wireless and remote control, and the Internet of Things

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the main elements of an electronically controlled industrial system		**D1** Critically examine the performance of an electronically controlled system to make recommendations for improvement
P1 Describe the main elements of 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	
LO2 Identify and specify the interface requirements between electronic, electrical and mechanical transducers and controllers		**D2** Critically investigate the behaviour of a given control system to compare different electrical, electronic and mechanical approaches to control
P3 Identify 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	
LO3 Apply practical and computer-based methods to design and test a measurement system		**D3** Critically evaluate the performance of an ideal measurement system compared to a real circuit
P5 Apply 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	

Pass	Merit	Distinction
LO4 Apply appropriate analytical techniques to predict the performance of a given system		**D4** Analyse an existing industrial system using appropriate analytical techniques. Provide justified recommendations to improve the performance
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	

Recommended Resources

Textbooks

BIRD, J. (2013) *Electrical Circuit Theory and Technology*. London: Routledge.

HUGHES, E. and others (2012) *Electrical and Electronic Technology*. London: Pearson.

REHG, J. A. and SARTORI, G. J. (2005*) Industrial Electronics.* Upper Saddle River: Prentice-Hall.

WILAMOWSKI, B. M. and IRWIN, J. D. (2011) *The Industrial Electronic Handbook: Fundamentals of Industrial Electronics.* Boca Raton: CRC Press.

Websites

http://www.bath.ac.uk/	University of Bath Patents (General Reference)
http://www.bsigroup.com/	Business Standards Institution Standards Catalogue (General Reference)
https://www.ieee.org/	Institute of Electrical and Electronics Engineers Standards (General Reference)
http://www.theiet.org/	Institution of Engineering and Technology (General Reference)
http://www.newelectronics.co.uk/	New Electronics Digital Magazine (Journals)
http://www.theiet.org/	Institution of Engineering and Technology (Journals)
http://www.epemag.com/	Everyday Practical Electronics (Journals)
https://www.ieee.org/	Institute of Electrical and Electronics Engineers (Journals)

Links

This unit links to the following related units:

Unit 19: Electrical and Electronic Principles

Unit 16: Instrumentation and Control Systems

Unit 46: Embedded Systems

Unit code	**A/615/1514**
Unit level	**5**
Credit value	**15**

Introduction

An embedded system is a device or product that contains one or more tiny computers hidden inside it. This 'hidden computer', usually a microcontroller, is used to control the device and give it added 'intelligence'. Embedded systems are a key aspect of modern engineering, and are applied in areas as diverse as automotive, medical, industrial, and in the home and office. In many cases, embedded systems are linked together in networks. Embedded systems are the basis of a new wave of engineering design and practice, notably in machine-to-machine communication, and in the Internet of Things.

This unit builds on introductory knowledge the student has already gained in electronic circuits. It develops their knowledge of computer hardware, focusing on the small, low-cost type of computer, i.e. a microcontroller, usually used in embedded systems. It then develops skill in devising circuits, which operate externally to the microcontroller, and interface with it; generally, these relate to sensors, actuators, human interface or data transfer. In parallel with this, the student will be developing programming skills, writing programmes that download straight to the microcontroller and cause it to interact with its external circuit. The student will also explore the wider context of embedded systems, learning how they are applied in many 'hi-tech' applications, in many cases revolutionising our ability to undertake certain activities.

Unit assessment will require the design, development, construction and commissioning of an embedded system, meeting a given design brief – developing 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:

1. Explore the principal features of a microcontroller and explain the purpose of its constituent parts.
2. Design and implement simple external circuitry, interfacing with a given microcontroller.
3. Write well-structured code in an appropriate programming language, to simulate, test and debug it.
4. Evaluate the applications of embedded systems in the wider environment, including in networked systems.

Essential Content

LO1 **Explore the principal features of a microcontroller and explain the purpose of its constituent parts**

Microcontroller architecture:

CPU (central processing unit), the instruction set, programme memory, data memory, input/output (I/O), data and address buses, van Neumann and Harvard structures

Peripherals, to include digital I/O, counter/timers, analogue to digital converter (ADC), pulse width modulation (PWM), serial peripheral interface (SPI), Universal Asynchronous Receiver/Transmitter (UART)

Memory types (overview only): Flash, Static RAM (Random Access Memory), EEPROM (Electrically Erasable Read Only Memory) and their applications

Simple interrupt concepts

LO2 **Design and implement simple external circuitry, interfacing with a given microcontroller**

Simple digital interfacing:

Switches, light-emitting diodes (LEDs), keypads, seven-segment displays

DC and ADC applications:

DC load switching (e.g. of small motor or solenoid), use of PWM to provide variable DC motor speed control

ADC application, including range and resolution. Signal conditioning for analogue inputs, including simple op amp circuits to provide gain or level shifting

Interfacing to external devices with serial capability, applying SPI and UART

Power supply and clock oscillator

LO3 **Write well-structured code in an appropriate programming language, to simulate, test and debug it**

The development cycle:

Integrated Development Environment, 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 language (which is likely to be C)

Language structure, data types, programme flow, looping, branching and conditional

Developing application code: initialisation, data input, conditional branching and looping, data output

Code simulation, download, test and debug

LO4 **Evaluate the applications of embedded systems in the wider environment, including in networked systems**

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 current trends in embedded systems, including the Internet of Things and machine to machine

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore the principal features of a microcontroller and explain the purpose of its constituent parts		**D1** Critically evaluate microcontroller architectures and subsystems exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)
P1 Examine the hardware interfaces and the software architecture of a selected microcontroller **P2** Explain the function of the main microcontroller elements	**M1** Evaluate microcontroller architectures and subsystems, exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)	
LO2 Design and implement simple external circuitry, interfacing with a given microcontroller		**D2** Critically evaluate the functionality of external circuitry under a range of operating conditions
P3 Design simple external circuits, sensors and actuators, from available designs **P4** Apply simple external circuits, demonstrating effective interfacing and adequate functionality	**M2** Adapt and improve simple external circuits, sensors and actuators, from available designs **M3** Assess simple external circuits and evaluate functionality	

Pass	Merit	Distinction
LO3 Write well-structured code in an appropriate programming language, to simulate, test and debug it		**D3** Critically evaluate the code developed through simulation and in the hardware, demonstrating excellent functionality
P5 Write well-structured working code to meet an identified need **P6** Test and debug code through simulation in the hardware, demonstrating functionality	**M4** Adapt and improve given examples to produce well-structured and reliable code with meaningful programme identifiers, to meet an identified need	
LO4 Evaluate the applications of embedded systems in the wider environment, including in networked systems		
P7 Evaluate current and emerging applications of embedded systems, e.g. in motor vehicles, health or the Internet of Things	**M5** Critically evaluate emerging applications of embedded systems, clearly identifying trends and recognising technical and economic factors	

Recommended Resources

Textbooks

BLUM, J. (2013) *Exploring Arduino*. Boston: Wiley.

TOULSON, R. and WILMSHURST, T. (2012) *Fast and Effective Embedded System Design: Applying the ARM*. Boston: Newnes.

WILMSHURST, T. (2009) *Designing Embedded Systems with PIC Microcontrollers: Principles and Applications*. 2nd Ed. Boston: Newnes.

Links

This unit links to the following related units:

Unit 52: Further Electrical, Electronic and Digital Principles

Unit 54: Further Control Systems Engineering

Unit 47: Analogue Electronic Systems

Unit code F/615/1515

Unit level 5

Credit value 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 and digital 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 and digital subsystems used in the development of complete electronic systems.

Learning Outcomes

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

1. Design single-stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances.
2. Develop functional subsystems through an understanding of the characteristics of operational amplifiers.
3. Examine the characteristics of information represented in analogue and digital format to assess techniques for the conversion of signals between analogue and digital formats.
4. Design electronic circuits using physical components.

Essential Content

LO1 **Design 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 hybrid-π model of the BJT

Show $g_m =\sim I_C/26mV$ for silicon BJT at room temperature

Bipolar junction transistor small signal amplifiers:

Four-resistor BJT common-emitter amplifier and its predicted AC voltage gain

ECAD 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:

Examples of class A, B, AB, C and D large signal amplifiers

Use of ECAD to investigate the characteristics of sample power amplifier circuits

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

LO2 **Develop functional subsystems through an understanding of the characteristics of operational amplifiers**

Operational amplifier components:

Circuit configuration and the operation of the long-tailed pair differential amplifier, current mirror and class AB amplifiers and relate these to circuits of operational amplifiers published in manufacturers' data sheets

Operational amplifier characteristics:

Characteristics of practical operational amplifiers including open-loop gain, input offset voltage, common mode input range, saturated output levels, slew rate and gain-bandwidth product

Describe the ideal operational amplifier model and relate these to the 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, inverting and non-inverting amplifier, summing amplifier, differential amplifier, linear voltage regulator, switched mode voltage regulator, differentiator, integrator, filters, sinusoidal oscillator, Schmitt trigger and Schmitt oscillator

Subsystem specifications and evaluations in time and frequency domains as appropriate

Use of ECAD tools

LO3 **Examine the characteristics of information represented in analogue and digital format to 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 and analogue to digital converters:

Evaluation and comparison of digital to analogue converters based on the binary weighted resistor and the R/2R ladder network techniques

Evaluate and comparison of analogue to digital converters based on the single ramp, successive approximation and parallel comparator (flash) techniques

Advantages of using non-linear conversion curves in communications applications

Techniques for multichannel operation using multiplexing and de-multiplexing techniques applied to both digital and analogue channels

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**

Subsystem design, implementation and evaluation:

Examples of electronic subsystems

Development of specifications to achieve a useful function and design of circuits to achieve this function

Simulation of design using ECAD tools

Building of circuits as designed, application of a range of appropriate bench tests to evaluate its operation, comparing its actual operation to the design specifications and simulation results

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Design single-stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances		**D1** Critically analyse the relationship between the circuit design and simulation results, making justified and operable recommendations for changes to the specifications of the circuits
P1 Design single-stage amplifier circuits and measure key aspects by simulation	**M1** Relate simulation results to circuit designs and analyse discrepancies	
LO2 Develop functional subsystems through an understanding of the characteristics of operational amplifiers		**D2** Communicate circuit designs to specialist audiences. The implications of manufacturers' data sheets are understood so that practical designs can be produced
P2 Present the key components of operational amplifiers **P3** Determine the operation of subsystems from the ideal model of the operational amplifier and by simulation results	**M2** Design operational amplifier subsystems simulated in time and frequency domains **M3** Critically analyse simulation results with reference to the expected results	
LO3 Examine the characteristics of information represented in analogue and digital format to assess techniques for the conversion of signals between analogue and digital formats		**D3** Critically valuate the implications of resolution, conversion time and non-linear conversion curves on accuracy and noise
P4 Examine the limitations of representing information in both analogue and digital form **P5** Specify the technical characteristics of converters to meet a given set of requirements	**M4** Critically evaluate the characteristics and limitations of converter topologies and their specific applications	

Pass	Merit	Distinction
LO4 Design electronic circuits using physical components		**D4** Communicate circuit designs to specialist audiences, showing variation of circuit function in simulations as a result of design changes or component tolerances
P6 Design an electronic circuit **P7** Simulate the construction and test the design on the bench	**M5** Critically analyse design equations, simulation and bench test results, ensuring discrepancies are recorded and explained	

Recommended Resources

Textbooks

LATHI, B. P. and DING, Z. (2009) *Modern Digital and Analog Communications Systems (Oxford Series in Electrical and Computer Engineering)*. Oxford: Oxford University Press.

STOREY, N. (2013) *Electronics: A Systems Approach*. 5th Ed. London: Pearson.

Links

This unit links to the following related unit:

Unit 19: Electrical and Electronic Principles

Unit 48: Manufacturing Systems Engineering

Unit code **J/615/1516**

Unit level **5**

Credit value **15**

Introduction

Manufacturing systems engineering is concerned with the design and ongoing operation and enhancement of the integrated elements within a manufacturing system. This 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 students will be able to:

1. Describe the principles of manufacturing system engineering and explain their relevance to the design and enhancement of manufacturing systems.
2. 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.
3. Outline the impact of different production planning approaches on the effectiveness of a manufacturing system.
4. Define the responsibilities of manufacturing systems engineering and review how they enable successful organisations to remain competitive.

Essential Content

LO1 **Describe the principles of manufacturing system 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**

Analysis tools:

Introduction to value stream mapping, and the value of both current state mapping and future state mapping

Bottle-neck analysis 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 versus 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Describe the principles of manufacturing system engineering and their relevance to the design and enhancement of manufacturing systems</td><td rowspan="2">D1 Apply value stream mapping to a production process to evaluate the efficiency of that process using the current state map to suggest improvements</td></tr>
<tr><td>P1 Illustrate the principles of manufacturing engineering
P2 Explain the relevance of manufacturing systems engineering to the design of a manufacturing system</td><td>M1 Evaluate the impact that manufacturing systems have on the success of a manufacturing organisation</td></tr>
<tr><td colspan="2">LO2 Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system</td><td rowspan="2">D2 Review value stream mapping against other production planning methodologies and justify its use as a production planning tool</td></tr>
<tr><td>P3 Apply value stream mapping to visualise a production process</td><td>M2 Identify optimisation opportunities through value stream mapping of a production process</td></tr>
<tr><td colspan="2">LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system</td><td rowspan="2">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</td></tr>
<tr><td>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</td><td>M3 Evaluate the effectiveness of production planning methods
M4 Explore the effectiveness of common production planning techniques to identify which production approach they complement</td></tr>
</table>

Pass	Merit	Distinction
LO4 Review the functions of manufacturing systems engineering and how they enable successful organisations to remain competitive		**D4** Critically consider the elements of an existing manufacturing system to appraise why this is successful
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 manufacturing systems engineering has on successful manufacturing organisations	

Recommended Resources

Textbooks

BICHENO, J. and HOLWEG, M. (2009) *The Lean Toolbox*. 4th Ed. Johannesburg: PICSIE Books.

CHOPRA, S. and MEINDL, P. (2015) *Supply Chain Management: Global Edition: Strategy, Planning, and Operation*. 6th Ed. London: Pearson Education Ltd.

SLACK, N. (2013) *Operations Management*. 7th Ed. London: 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 an MES (Article)

Links

This unit links to the following related units:

Unit 49: Lean Manufacturing

Unit 50: Advanced Manufacturing Technology

Unit 51: Sustainability

Unit 49: Lean Manufacturing

Unit code L/615/1517

Unit level 5

Credit value 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 organisation types and sizes, 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 effective and committed practitioners 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 practising lean. 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, the Toyota Production System (TPS), 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 common principles of lean manufacturing, compare the TPS with the now more widely adopted generic approaches to lean manufacturing, use a range of the process improvement tools used within lean manufacturing and demonstrate effective communication skills to lead the process of continuous improvement across an organisation.

Learning Outcomes

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

1. Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success.
2. Evaluate the Toyota Production System against the now more widely adopted generic approaches to lean manufacturing.
3. Specify a range of the process improvement tools used within lean manufacturing.
4. Demonstrate effective communication skills 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

Defining lean and its importance to the customer

Identifying and eliminating material and process waste that adds no value from the customer's perspective

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, employees and 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 Toyota Production System against the now more widely adopted generic approaches to lean manufacturing**

Toyota Production System:

Research the Toyota Production System (TPS)

Identify the fundamental elements of the TPS and the motivation behind creating the TPS

Compare TPS with the recognised theory and production systems publicised by other global

manufacturers; how they differ and how they are similar

How the common principles are now being adopted outside manufacturing

LO3 **Specify a range of the process improvement tools used within lean manufacturing**

Common tools and techniques associated with lean manufacturing and process improvement:

7 Wastes, continuous flow, Kanban (Pull System), Just-in-time, lean simulation activities, value stream mapping, Poke Yoke, 5 Whys (Root-Cause Analysis), Total Preventative Maintenance

Plan-do-check-act (PDCA), Single Minute Exchange of Dies (SMED), A3 reporting, Visual Management

Selecting the most appropriate improvement tool to tackle a problem:

Tools for improving quality and delivery

LO4 **Demonstrate effective communication skills 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)

Identify factors that influence engagement within a group, facilitation skills and change management

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		**D1** Critically evaluate the advantages and disadvantages of implementing a lean production system
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	
LO2 Evaluate the Toyota Production System against the now more widely adopted generic approaches to lean manufacturing		**D2** Critically evaluate the Toyota Production System in comparison to a researched alternative, determining the elements that are critical in making the approach successful
P2 Distinguish the principles of the Toyota Production System **P3** Research alternative lean production system approaches **P4** Examine the origins of lean and specify its early applications	**M3** Critically analyse alternative examples of lean production systems to determine the common principles with reference to the Toyota Production System	
LO3 Specify a range of the process improvement tools used within lean manufacturing		**D3** Make a supported and justified recommendation for a lean tool to be applied in addressing a specified process improvement
P5 Specify which tools are commonly associated with lean manufacturing and determine what context they would be applied in	**M4** Evaluate how the most common lean tools can be applied to eliminate waste in a manufacturing process	

Pass	Merit	Distinction
LO4 Demonstrate effective communication skills to lead the process of continuous improvement across an organisation		**D4** Critically evaluate the importance of the skills required to successfully deploy change in an organisation
P6 Demonstrate and deliver a communication approach that can be taken to manage change in an organisation	**M5** Evaluate the impact of this communication approach, including an evaluation of impact on employees and personal effectiveness	

Recommended Resources

Textbooks

BICHENO, J. and HOLWEG, M. (2009) *The Lean Toolbox*. 4th Ed. Johannesburg: PICSIE Books.

LIKER, J. and MEIER, D. (2006) *The Toyota Way Fieldbook*. New York: McGraw-Hill.

WOMACK, J., JONES D. and ROOS, D. (1990) *The Machine That Changed the World*. New York: Free Press.

Links

This unit links to the following related units:

Unit 48: Manufacturing Systems Engineering

Unit 50: Advanced Manufacturing Technology

Unit 51: Sustainability

Unit 50: Advanced Manufacturing Technology

Unit code	**R/615/1518**
Unit level	**5**
Credit value	**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.

To meet the changing customer expectation 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.

Industry 4.0 is the term that has been adopted to describe the 'fourth' industrial revolution currently underway 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 and evaluate the potential of using advanced manufacturing technologies to improve the competitive advantage of the organisations adopting them. Students will develop knowledge and understanding of advanced manufacturing technologies, digitalisation and a range of advanced manufacturing technologies. They will also develop their own research activities into latest developments.

Learning Outcomes

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

1. Recognise a range of advanced manufacturing processes and cite examples of where they are most effective.
2. Analyse advanced manufacturing technologies to determine their appropriateness for an application or process.
3. Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies.
4. Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer.

Essential Content

LO1 **Rec ognise a range of advanced manufacturing processes to cite examples of where they are most effective**

Manufacturing processes:

Pressing and forming

Casting and moulding

Joining and soldering

Mixing

Final assembly

Packaging

Material handling

Quality control/inspection

Advanced manufacturing processes:

Additive manufacturing technology (e.g. replacing forming, moulding, pressing),

3D printing, impact on rapid prototyping, availability of spares/obsolete parts, medical components available and customised

Mass customisation through 3D printing, opening up a self-serve market

Robotics/human interface and automation, high-precision technology and productivity (e.g. aerospace, automotive, electronics assembly)

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 **Analyse 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

Examples of using 3D printing and other forms of additive manufacturing to produce medical equipment, spare parts for items that may have become obsolete, mass customisation – what the customer wants, when they want it

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 and 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, costs, time to market and customer satisfaction (using healthcare/medical examples such as hip joint, traditional method versus mass customisation and the possible use of 3D printing)

3D printing and its availability is opening up new markets but also new business models for organisations

Explore the future possibilities for self-serve/self-production of items

LO4 **Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer**

Next industrial revolution:

Industry 4.0.

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 – there is a growing demand and desire for individual products. In 1908, referring to the Model T, Henry Ford said, 'you can have any colour as long as it's black'. In 2015 you can have trillions of variations of the Ford F150

Advanced manufacturing technology and the ability to manage complexity is key to that realisation

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 – 25 per cent of all energy used is required by industry alone

Big data – the development of an ever-connected production environment alongside cloud computing presents a challenge of having a stream of production data and the need to analyse this to make timely, informed decisions

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Recognise a range of advanced manufacturing processes to cite examples of where they are most effective</td><td rowspan="2">D1 Research and evaluate a manufactured product and identify the technology used</td></tr>
<tr><td>P1 Recognise a range of advanced manufacturing process or technologies and cite examples of where they are most effective</td><td>M1 Compare a traditional manufacturer to one employing advanced manufacturing to discuss the fundamental differences</td></tr>
<tr><td colspan="2">LO2 Analyse advanced manufacturing technologies to determine their appropriateness for an application or process</td><td rowspan="2">D2 Examine the potential justification for an organisation to invest in advanced manufacturing technology</td></tr>
<tr><td>P2 Analyse advanced manufacturing technologies to determine their appropriateness for an application or process</td><td>M2 Explore how advanced manufacturing could be applied, and give examples of where technology would be suited</td></tr>
<tr><td colspan="2">LO3 Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies</td><td rowspan="2">D3 Critically evaluate the impact of using advanced manufacturing technology rather than the existing method on both the customer and the manufacturer</td></tr>
<tr><td>P3 Analyse an existing manufactured product and identify the key technology used to produce the item</td><td>M3 Evaluate the effectiveness of the current method and suggest an alternative advanced manufacturing technology</td></tr>
<tr><td colspan="2">LO4 Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer</td><td rowspan="2">D4 Investigate and justify the types of industry or product that would benefit most from an innovative advanced manufacturing approach</td></tr>
<tr><td>P4 Evaluate the concept of a fourth industrial revolution

P5 Identify the key elements of Industry 4.0</td><td>M4 Evaluate the impact of advanced manufacturing on both manufacturers and the customer</td></tr>
</table>

Recommended Resources

Textbooks

LEFTERI, C. (2012) *Making It: Manufacturing Techniques for Product Design*. 2nd Ed. London: Laurence King.

WRIGHT, P. K. (2000) *21st Century Manufacturing*. Upper Saddle River: Prentice-Hall.

Websites

https://www.gov.uk/	GOV.UK Future of manufacturing: a new era of opportunity and challenge for the UK (Report)
https://w3.siemens.com/	Siemens The Future of Manufacturing (General Reference)
https://hvm.catapult.org.uk/	Catapult High Value Manufacturing (General Reference)

Links

This unit links to the following related units:

Unit 48: Manufacturing Systems Engineering

Unit 49: Lean Manufacturing

Unit 51: Sustainability

Unit 51: Sustainability

Unit code Y/615/1519

Unit level 5

Credit value 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:

1. Determine the nature and scope of the technical challenges of ensuring sustainable development.
2. Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems.
3. Evaluate the use of alternative energy generation techniques in relation to their contribution to a low carbon economy.
4. 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 2^0 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		**D1** Critically analyse how the interrelationship between the three key areas of technical challenges can be managed systemically to ensure maximum sustainability
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	
LO2 Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems		**D2** Critically analyse how a systemic approach can be used to support interdisciplinary collaboration in developing sustainable infrastructures
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	

Pass	Merit	Distinction
LO3 Evaluate the use of alternative energy generation techniques in relation to their contribution to 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
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	
LO4 Analyse a variety of data sources to estimate 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
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	

Recommended Resources

Textbooks

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.

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^{0}c Will Be Harder Than We Think*. Whitefox Publishing.

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 4: Managing a Professional Engineering Project

Unit 35: Professional Engineering Management

Unit 52: Further Electrical, Electronic and Digital Principles

Unit code L/615/1520

Unit level 5

Credit value 15

Introduction

Almost every aspect of our lives relies on electrical-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 20: Electrical, Electronic and Digital Principles.

The emphasis in this unit will be on developing a structured approach to the analysis of AC single-phase and three-phase powered circuitry. This will help students to arrive at a 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 cope with 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:

1. Use appropriate mathematical techniques to solve a range of electrical and electronic problems.
2. Apply appropriate circuit theorems to solve problems in electrical networks.
3. Use appropriate laboratory and computer simulation techniques to investigate both analogue and digital circuits and interpret the results.
4. Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions.

Essential Content

LO1 **Use appropriate mathematical techniques to solve a range of electrical and electronic problems**

Formal steady state circuit analysis:

Determinants, mesh analysis and nodal analysis (and their comparison)

Analysis using ideal sources, superposition theorem

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

LO2 **Apply appropriate circuit theorems to solve problems in electrical networks**

Three-phase theory:

Application of trigonometric methods to solution of phasor diagrams

Application of complex numbers to represent quantities in AC circuits

Single-phase representation

Solution of balanced three-phase circuits

Complex notation applied to three-phase, unbalanced loads, unconnected neutral point

Power, reactive power and power factor correction for three-phase systems

LO3 **Use appropriate laboratory and computer simulation techniques to investigate both analogue and digital circuits and interpret the results**

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

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, 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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Use appropriate mathematical techniques to solve a range of electrical and electronic problems		**D1** Apply an accurate approach to problem solving with clear justification of methods used with a high standard of explanation for each method
P1 Produce basic solutions to electrical and electronic problems to a satisfactory standard, but with some misunderstandings	**M1** Provide reasoned solutions to problems showing a logical approach and using a range of mathematical methods	
LO2 Apply appropriate circuit theorems to solve problems in electrical networks		**D2** Evaluate electrical theory by using a variety of mathematical and other methods to produce accurate solutions with clear justification of the methods used
P2 Use electrical network theory to provide solutions to problems to a satisfactory standard, with some level of ambiguity and errors	**M2** Apply electrical network theory and provide accurate solutions to problems showing a logical approach	
LO3 Use appropriate laboratory and computer simulation techniques to investigate both analogue and digital circuits and interpret the results		**D3** Present a clear evaluation of the operation of current analogue and digital logic circuits by comparing their predicted behaviour with the simulated, theoretical and practical results
P3 Use appropriate laboratory and computer simulation techniques to explain the performance of digital logic circuits and analogue circuits	**M3** Explore analogue and digital logic circuits to show a structured approach to the solutions of problems using a variety of methods	
LO4 Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions		**D4** Evaluate the application of theory, simulation and practical investigation of a number of circuits using non-linear circuits
P4 Describe 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 the effects of non-linear behaviour in a number of differing circuits	

Recommended Resources

Textbooks

BIRD, J. (2013) Electrical Circuit Theory and Technology. London: Routledge.

HUGHES, E. and others (2012) Electrical and Electronic Technology.
London: Pearson.

REHG, J. A. and SARTORI, G. J. (2005) Industrial Electronics. Upper Saddle River: Prentice-Hall.

WILAMOWSKI, B. M. and IRWIN, J. D. (2011) The Industrial Electronic Handbook: Fundamentals of Industrial Electronics. Boca Raton: CRC Press.

Websites

http://www.bath.ac.uk/	University of Bath *Patents* (General Reference)
http://www.bsigroup.com	British Standards Institution *Standards* (General Reference)
https://www.ieee.org	Institute of Electrical and Electronics Engineers *Standards* (General Reference)
https://app.knovel.com/	Knovel (Research)
https://www.esdu.com	Engineering Science Data Unit (General Reference)
http://www.theiet.org/	Institute of Engineering and Technology (General Reference)

Links

This unit links to the following related unit:

Unit 19: Electrical and Electronic Principles

Unit 53: Utilisation of Electrical Power

Unit code R/615/1521

Unit level 5

Credit value 15

Introduction

The supply, processing and usage of electrical energy are leading preoccupations around the world today, with significant technical, economic, environmental and societal implications. Engineers must engage seriously with this issue and 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:

1. Examine the demands, sources and construction of electrical power generation and distribution systems.
2. Explore the interconnections of power systems and their protection to explain the critical processes, the effects of failure and the importance of electrical safety.
3. Evaluate the effectiveness of forms of engineering activity to promote sustainable development.
4. Discuss new and emerging methods to optimise energy usage, conversion and storage techniques.

Essential Content

LO1 **Examine the demands, sources and construction of electrical power generation and distribution systems**

Demands of a power generation and transmission system:

Total power demands of a defined 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 Third World economy, analysis of the trends of energy supply and demand data to predict future energy requirements and budgets

Identification of the 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

LO2 **Explore the interconnections of power systems and their protection to explain 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, 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 methods to measure and reduce harmonics

The need to protect 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

Definition 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 using varied and distributed generation systems and managing the generation of power

Techniques for optimising energy usage and conversion:

Evaluating 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, characteristics of 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 and construction of electrical power generation and distribution systems		**D1** Critically evaluate governmental policies for managing the energy budget in the long term, making justified recommendations
P1 Examine the key aspects of a country's energy supply, demand and losses to create a balanced energy budget	**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	
LO2 Explore the interconnections of power systems and their protection to explain the critical processes, the effects of failure and the importance of electrical safety		**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
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	

Pass	Merit	Distinction
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		**D3** Critically evaluate novel forms of energy generation using recent, peer-reviewed publications, taking into account efficiency, costs, security and environmental implications
P4 Evaluate the technology of renewable sources of energy, taking into account efficiency, costs, security and environmental implications	**M3** Illustrate the application of renewable energy sources to meet existing demands, taking into account efficiency, costs, security and environmental implications	
LO4 Discuss new and emerging methods to optimise energy usage, conversion and storage techniques		**D4** Critically evaluate novel forms of energy optimisation and efficiency and their applications using recent, peer-reviewed publications
P5 Discuss representative examples of existing and emerging methods of energy optimisation	**M4** Evaluate the environmental effects of applying known energy optimisation techniques	

Recommended Resources

Textbooks

BAYLIS, C. and HARDY, B. (2012) *Transmission and Distribution Electrical Engineering*. Boston: Newnes.

BREEZE, P. A. (2014) *Power Generation Technologies*. 2nd Ed. Boston: Newnes.

Journals

Power Engineering Journal (IEEE, online)

Links

This unit links to the following related units:

Unit 41: Distributed Control Systems

Unit 44: Industrial Power, Electronics and Storage

Unit 54: Further Control Systems Engineering

Unit code Y/615/1522

Unit level 5

Credit value 15

Introduction

Control engineering is usually found at the top level of large projects in 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 students with the fundamental knowledge of the principles of control systems and a basic 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, and grasp fundamental 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:

1. Discuss the basic concepts of control systems and their contemporary applications.
2. Analyse the elements of a typical, high-level control system and its model development.
3. Analyse the structure and behaviour of typical control systems.
4. Explain the application of control parameters to produce optimum performance of a control system.

Essential Content

LO1 **Examine the basic concepts of control systems and their contemporary applications**

Background, terminology, underpinning principles and system basics:

Brief history of control systems and their industrial relevance

Control system terminology and identification including plant, process, system, disturbances, inputs and outputs, initial time, additivity, homogeneity, linearity and stability

Basic control systems properties and configurations, classification and performance criteria of control systems

Block diagram representation of simple control systems and their relevance in industrial application

Principles of Transfer Function (TF) for open and closed-loop systems, use of current computational tools in control systems (e.g. Matlab©, Simuliunk©, Labview©).

LO2 **Explore the elements of a typical, 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 systems using current computational tools (e.g. Matlab©/Simulink©)

LO3 **Analyse the structure and behaviour of typical 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©) to model, simulate and analyse the dynamic behaviour of simple open and closed-loop control systems

LO4 **Explain 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, on 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©, Simuliunk©, Labview©) to analyse the effects of each P-I-D term, individually and in combination on a control system

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Examine the basic concepts of control systems and their contemporary applications		**D1** Evaluate the ability of the PID controller to demonstrate high-level control techniques
P1 Examine the basic concepts of control systems using block diagram representation and simplifications **P2** Model simple open and closed-loop control systems simulation software	**M1** Apply advanced modelling techniques using commercially available control software **M2** Develop the block diagram of a closed-loop system for the position control of a DC motor using a PID controller	
LO2 Explore the elements of a typical, high-level control system and its model development		**D2** Perform high-level self-tuning techniques
P3 Explore the main building blocks for high-level electrical and mechanical control systems **P4** Apply Laplace transforms to basic mechanical or electrical control problems	**M3** Analyse electrical, mechanical and electro-mechanical systems using appropriate mathematical models	
LO3 Analyse the structure and behaviour of typical control systems		**D3** Evaluate the performance of an electro-mechanical system

Pass	Merit	Distinction
P5 Analyse the behaviour and response of first and second-order systems **P6** Analyse the stability of control systems and the techniques used to improve stability in these systems	**M4** Justify the stability of a system using analytical techniques	
LO4 Examine the application of control parameters to produce optimum performance of a control system		**D4** Evaluate the stability of a control system
P7 Examine the role and implementation of the P, I, D controllers in a simple electrical and mechanical control system **P8** Examine the effects of the P, I, 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	

Recommended Resources

Textbooks

DABNEY, J. B. and HARMAN, T. L. (2003) *Mastering Simulink*. Upper Saddle River: Prentice-Hall.

DORF, R. C. and BISHOP, R. H. (2014) *Modern Control Systems*. 12th Ed. London: Pearson.

NISE, N. S. (2011) *Control Systems Engineering*. 6th Ed. Boston: John Wiley & Sons, Inc.

Links

This unit links to the following related units:

Unit 41: Distributed Control Systems

Unit 16: Instrumentation and Control Systems

Unit 63: Industrial Services

Unit code K/615/1525

Unit level 5

Credit value 15

Introduction

Behind the scenes in many modern-day manufacturing facilities lies a complex system of services that powers production both day and night. The underlying aim of this unit is to enhance 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.

Students 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 plants, and the applications and precepts of refrigeration plants 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:

1. Apply the operating principles of electrical power and lighting systems.
2. Investigate the applications and efficiency of industrial compressors.
3. Discuss the provision of steam services for process and power use.
4. 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		**D3** Evaluate the modifications made to the basic steam raising systems to improve their overall efficiency
P7 Demonstrate the need for superheated steam in power-generating plants **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	
LO4 Review industrial refrigeration and heat pump systems		**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 an academic poster/presentation
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 the economics of heat pumps **M5** Discuss the apparent contradiction between refrigeration cycles and the second law	

Recommended Resources

Textbooks

CIBSE (2002) *Code for Lighting*. Oxford: Butterworth-Heinemann.

DUNN, D. (2001) *Fundamental Engineering Thermodynamics.* Harlow: Longman.

EASTOP, T. D. and MCCONKEY, A. (1996) *Applied Thermodynamics for Engineering Technologists*. 5th Ed. Upper Saddle River: Prentice-Hall.

HUGHES, A. (2013) *Electric Motors and Drives: Fundamentals, Types and Applications.* 4th Ed. Boston: Newnes.

ROGERS, G. F. C. and MAYHEW, Y. R. (1994) *Thermodynamic and Transport Properties of Fluids: S. I. Units*. 5th Ed. Boston: Wiley-Blackwell.

Websites

http://www.freestudy.co.uk	Free Study (Tutorials)

Links

This unit links to the following related units:

Unit 13: Fundamentals of Thermodynamics and Heat Engines

Unit 38: Further Thermodynamics

Unit 64: Thermofluids

Unit 64: Thermofluids

Unit code	**M/615/1526**
Unit level	**5**
Credit value	**15**

Introduction

In everyday life you're 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 on the back of a fire door, thermofluids are constantly around us.

The aim of this unit is 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.

Students will examine thermodynamic fundamental 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.

Additionally, 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:

1. Review industrial thermodynamic systems and their properties.
2. Examine the operation of practical steam and gas turbine plants.
3. Illustrate the properties of viscosity in fluids.
4. Analyse fluid systems and hydraulic machines.

Essential Content

LO1 **Review industrial thermodynamic systems and their properties**

Thermodynamic systems:

Power generation plant

Significance of 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 processes)

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

LO2 **Examine the operation of practical steam and gas turbine plants**

Steam and gas turbine plant:

Principles of operation of steam and gas turbine plant

Use of property diagrams to analyse plant

Characteristics of steam/gas turbine plant as used in energy supply

Energy-saving options adopted in steam plants operating on a modified Rankine cycle

Performance characteristics of steam and gas power plants

Cycle efficiencies: turbine isentropic efficiencies and overall relative efficiency

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

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

Hydraulic machines:

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Review industrial thermodynamic systems and their properties		**D1** Analyse an operational industrial thermodynamic system in terms of work done
P1 Discuss the operation of industrial thermodynamic systems and their properties **P2** Describe the application of the first law of thermodynamics to industrial systems **P3** Illustrate the relationships between system constants for a perfect gas	**M1** Determine the index of compression in polytrophic processes	
LO2 Examine the operation of practical steam and gas turbine plants		**D2** Evaluate the modifications made to the basic Rankine cycle to improve the overall efficiency of steam power plants
P4 Explain the principles of operation of steam turbine plants **P5** Calculate overall steam turbine plant efficiencies using 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	
LO3 Illustrate the effects of viscosity in fluids		**D3** Compare the results of a viscosity test on a Newtonian fluid with that given on a data sheet and explain any discrepancies
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	

Pass	Merit	Distinction
LO4 Analyse fluid systems and hydraulic machines		**D4** Evaluate the use of dimensionless analysis using the Buckingham Pi Theorem for a given industrial application
P9 Examine 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 Reynolds number on fluid flow in a given system	

Recommended Resources

Textbooks

DUNN, D. (2001) *Fundamental Engineering Thermodynamics*. Harlow: Longman.

EASTOP, T. D. and MCCONKEY, A. (1996) *Applied Thermodynamics for Engineering Technologists.* 5th Ed. Upper Saddle River: Prentice-Hall.

MASSEY, B. S. and WARD-SMITH, J. (2011) *Mechanics of Fluids*. 9th Ed. Oxford: Spon Press.

ROGERS, G. F. C. and MAYHEW, Y. R. (1994) T*hermodynamic and Transport Properties of Fluids: S. I. Units*. 5th Ed. Boston: Wiley-Blackwell.

Websites

http://www.freestudy.co.uk	Free Study (Tutorials)
http://www.khanacademy.org	Khan Academy (Tutorials)

Links

This unit links to the following related units:

Unit 13: Fundamentals of Thermodynamics and Heat Engines

Unit 12: Fluid Mechanics

Unit 29: Electro, Pneumatic and Hydraulic Systems

Unit 65: Nuclear Reactor Operations

Unit code	**D/615/1540**
Unit level	**5**
Credit value	**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:

1. Apply physics analysis to understand the fission chain reaction and how it is controlled in a nuclear reactor.
2. 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.
3. Apply physics and thermal-hydraulic analysis to model aspects of reactor operation during start-up, sub-power operation, operation at power and shut-down.
4. 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Apply physics analysis to understand the fission chain reaction and how it is controlled in a nuclear reactor</td><td rowspan="2">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</td></tr>
<tr><td>P1 Calculate the reactivity of a simple homogeneous reactor of specified dimensions and composition using standard physics analysis</td><td>M1 Calculate and explain the variation in reactivity of a homogeneous reactor with core age as the composition changes</td></tr>
<tr><td colspan="2">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</td><td rowspan="2">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</td></tr>
<tr><td>P2 Calculate temperature using thermal-hydraulic analysis profiles in the core of a reactor operating at a steady state</td><td>M2 Compare calculated temperature profiles with thermal limits and determine the maximum power generation</td></tr>
<tr><td colspan="2">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</td><td rowspan="2">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</td></tr>
<tr><td>P3 Use mathematical models of the physics and thermal hydraulics of a reactor to explain and predict critical aspects of reactor operation</td><td>M3 Use mathematical models of the physics and thermal-hydraulic behaviour of the reactor to estimate advanced key parameters including maximum power and reactivity</td></tr>
</table>

Pass	Merit	Distinction
LO4 Analyse the processes that generate radiation and radioactivity in a nuclear reactor and explain how these are controlled		**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
P4 Analyse the sources of radiation and radioactivity in an operating PWR	**M4** Calculate levels of radiation and activation in an operating PWR	

Recommended Resources

Textbooks

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 65: Nuclear Reactor Operations

Unit 66: Nuclear Reactor Chemistry

Unit 69: Nuclear Fuel Cycle Technology

Unit 66: Nuclear Reactor Chemistry

Unit code	**H/615/1541**
Unit level	**5**
Credit value	**15**

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 students will be able to:

1. Show how the reactions of water, water chemistry control and reactor water treatments operate in relation to PWR reactors.
2. Evaluate chemistry and chemical changes relevant to fresh and used nuclear fuel, fuel storage ponds and reactor coolants in PWR.
3. Discuss the importance, formation, type and characteristics of corrosion and corrosion products and mitigation methods present in nuclear reactor cooling systems.
4. 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Show how the reactions of water, water chemistry control and reactor water treatments operate in relation to PWR reactors</td><td rowspan="2">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</td></tr>
<tr><td>P1 Show how the basic phenomena concerning water and reactor water chemistry apply to water treatment in PWR</td><td>M1 Evaluate the effects of the various phenomena concerning water and reactor water chemistry and water treatment in PWR</td></tr>
<tr><td colspan="2">LO2 Evaluate chemistry and chemical changes relevant to fresh and used nuclear fuel, fuel storage ponds and reactor coolants in PWR</td><td rowspan="2">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</td></tr>
<tr><td>P2 Evaluate the chemistry and chemical changes relevant to nuclear fuel, fuel storage ponds and reactor coolants in PWR</td><td>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</td></tr>
<tr><td colspan="2">LO3 Discuss the importance, formation, type and characteristics of corrosion and corrosion products and mitigation methods present in nuclear reactor cooling systems</td><td rowspan="2">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</td></tr>
<tr><td>P3 Discuss the basic formation mechanisms, types and characteristics of corrosion and corrosion products present in nuclear reactor cooling systems</td><td>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</td></tr>
</table>

Pass	Merit	Distinction
LO4 Examine the techniques and methods used for coolant chemistry control in modern reactors		**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
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	

Recommended Resources

Textbooks

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 68: Nuclear Reactor Materials

Unit 67: Nuclear Radiation Protection Technology

Unit code	**K/615/1542**
Unit level	**5**
Credit value	**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:

1. Apply knowledge of the science of radiation to design, implement and measure the effectiveness of radiation protection controls.
2. Interpret radiation protection legislation and formulate management advice on radiation protection strategies in accordance with the relevant approved code of practice.
3. Review radiation protection strategies in the workplace to ensure that radiation exposures are as low as reasonably practicable.
4. 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		**D1** Quantitatively analyse the efficacy of radiation protection measures using the science of radioactivity and radiation
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	
LO2 Interpret radiation protection legislation and formulate management advice on radiation protection strategies in accordance with the relevant approved code 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
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	
LO3 Review radiation protection strategies in the workplace to ensure that radiation 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
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	

Pass	Merit	Distinction
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		**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
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	

Recommended Resources

Textbooks

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 72: Nuclear Safety Case Development

Unit 68: Nuclear Reactor Materials

Unit code	**M/615/1543**
Unit level	**5**
Credit value	**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:

1. Illustrate the importance of atomic arrangement on mechanical properties of reactor core materials.
2. Analyse mechanical and thermal properties and manufacturing techniques that are considered in the design and materials selection of PWR components.
3. Analyse the changes in material properties that occur in PWR components as a result of radiation (α, β, γ and neutron) exposure.
4. 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		**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
P1 Illustrate common crystal structures and various material properties relevant to reactor core materials	**M1** Discuss how atomic arrangements impact material properties	
LO2 Analyse mechanical and thermal properties and manufacturing techniques that are considered in the design and materials selection of PWR components		**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
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	
LO3 Analyse the changes in material properties that occur in PWR components as a result of radiation (α, β, γ and neutron) 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
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	

Pass	Merit	Distinction
LO4 Discuss the use of zirconium and 20/25/Nb stainless steel in nuclear reactors		**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
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	

Recommended Resources

Textbooks

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 66: Nuclear Reactor Chemistry

Unit 69: Nuclear Fuel Cycle Technology

Unit code T/615/1544

Unit level 5

Credit value 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:

1. 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.
2. Examine the safety and environmental issues arising at each step in the nuclear fuel cycle and explain how the associated challenges are being met.
3. 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.
4. 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	
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		**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
P5 Calculate the cost of a reactor fuel load	**M4** Calculate the savings from reprocessing and recycling on the costs of a fuel load	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">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</td><td rowspan="2">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</td></tr>
<tr><td>P6 Review the key steps in nuclear fuel cycles based on thorium and fast reactors</td><td>M5 Discuss the technological challenges involved in the development of thorium and fast reactor fuel cycles</td></tr>
</table>

Recommended Resources

Textbooks

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

NEA/OECD Publication, *Uranium Resources, Production and Demand* ('The Red Book'), published annually.

Websites

World Nuclear Association website: http://www.world-nuclear.org/

Unit 70: Nuclear Decommissioning and Radioactive Waste Management Technologies

Unit code	**A/615/1545**
Unit level	**5**
Credit value	**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:

1. Evaluate a range of specialist technologies developed for nuclear decommissioning and radioactive waste immobilisation.

2 Review the management of decommissioning, the deployment of technological solutions and the process of hazard reduction, using case studies.

3. Discuss the regulatory framework governing the safety and environmental impacts of nuclear decommissioning and radioactive waste management.

4. 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Evaluate a range of specialist technologies developed for nuclear decommissioning and radioactive waste immobilisation</td><td rowspan="2">D1 Review research activities aimed at developing improved techniques and critically assess techniques used in nuclear decommissioning, identifying areas for improvement</td></tr>
<tr><td>P1 Evaluate the main techniques used in nuclear decommissioning

P2 Evaluate the main techniques used for radioactive waste immobilisation</td><td>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</td></tr>
<tr><td colspan="2">LO2 Review the management of decommissioning, the deployment of technological solutions and the process of hazard reduction, using case studies</td><td rowspan="2">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</td></tr>
<tr><td>P3 Review the decommissioning techniques used in a particular decommissioning project</td><td>M3 Assess the application of technology to decommissioning in a particular project and summarise the key lessons learned</td></tr>
<tr><td colspan="2">LO3 Discuss the regulatory framework governing the safety and environmental impacts of nuclear decommissioning and radioactive waste management</td><td rowspan="2">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</td></tr>
<tr><td>P4 Discuss the principles of safety and environmental regulation of nuclear decommissioning projects</td><td>M4 Assess the regulatory arrangements for safety and environmental protection in decommissioning projects</td></tr>
</table>

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO4 Evaluate current arrangements and future plans for radioactive waste disposal in the UK and critically assess strategic and technological bases for the plans</td><td rowspan="2">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</td></tr>
<tr><td>P5 Evaluate arrangements for LLW disposal in the UK and outline plans for a GDF</td><td>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</td></tr>
</table>

Recommended Resources

Textbooks

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 65: Nuclear Reactor Operations

Unit 66: Nuclear Reactor Chemistry

Unit 68: Nuclear Reactor Materials

Unit 71: Nuclear Criticality Control

Unit code	**F/615/1546**
Unit level	**5**
Credit value	**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:

1. 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.
2. 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.
3. Investigate how facilities can be designed and operated to reduce the likelihood and/or consequences of an unplanned criticality excursion.
4. 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		**D1** Quantify the limitations of both hand and computer-based calculations and make recommendations on how the criticality assessment analysis could be improved
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	
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		**D2** Critically evaluate the regulatory approaches and industry standards used for criticality control in a specified number of countries, including the UK and USA
P2 Investigate the underlying regulatory requirements pertaining to criticality control	**M2** Assess both regulatory and industry standards for criticality control	
LO3 Investigate how facilities can be designed and operated to reduce the likelihood and/or consequences of an unplanned criticality excursion		**D3** Critically evaluate the design, operational, administrative and safety management arrangements for criticality control at a real nuclear facility
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	
LO4 Examine previous recorded criticality accidents, analyse the root causes and draw conclusions on 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
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	

Recommended Resources

Textbook

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 67: Nuclear Radiation Protection Technology

Unit 72: Nuclear Safety Case Development

Unit 72: Nuclear Safety Case Development

Unit code J/615/1547

Unit level 5

Credit value 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:

1. 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.
2. 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.
3. 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.
4. 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		**D1** Critically review examples of safety cases, identify common shortcomings and cite examples of best practice
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	
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		**D2** Apply 'industry-standard' fault and event tree software applications to a nuclear facility, describe its limitations and recommend areas for further development
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	
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		**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
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	

Pass	Merit	Distinction
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		**D4** Construct a multi-layered safety case in terms of claim, argument and evidence and explicitly link the safety case to plant operating limits
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	

Recommended Resources

Textbooks

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 67: Nuclear Radiation Protection Technology

Unit 71: Nuclear Criticality Control

11. Appendices

Appendix 1: Mapping of HND in Engineering against FHEQ Level 5

Key	
KU	Knowledge and understanding
CS	Cognitive skills
AS	Applied skills
TS	Transferable skills

The qualification will be awarded to students who have demonstrated:

FHEQ Level 5 descriptor		**Engineering HND programme outcome**
Knowledge and critical understanding of the well-established principles of their area(s) of study, and of the way in which those principles have developed.	KU1	Knowledge and understanding of the fundamental principles and practices of the contemporary global engineering industry.
	KU2	Knowledge and understanding of the external engineering environment and its impact upon local, national and global levels of strategy, behaviour, management and sustainability.
	KU3	Understanding and insight into different engineering practices, their diverse nature, purposes, structures and operations, and their influence upon the external environment.
	KU4	A critical understanding of the ethical, environmental, legal, regulatory, professional and operational frameworks within which engineering operates.
	KU5	A critical understanding of the processes, practices and techniques for effective management of products, processes, services and people.
	KU6	A critical understanding of the evolving concepts, theories and models within the study of engineering across the range of operational alternatives.
	KU7	An ability to evaluate and analyse a range of concepts and theories, models and techniques to make appropriate engineering operational and management decisions.

FHEQ Level 5 descriptor		Engineering HND programme outcome
	KU8	An appreciation of the concepts and principles of continuing professional development, staff development, team dynamics, leadership and reflective practice as strategies for personal and people development.
	KU9	Knowledge and understanding of how the key areas of engineering and the environment it operates within influence the development of people and businesses.
	KU10	An understanding of the skills, techniques and methodologies used to resolve problems in the workplace.
	KU11	Knowledge and understanding of human–machine interaction to inform the development of good design and fitness for purpose.

FHEQ Level 5 descriptor		Engineering HND programme outcome
Ability to apply underlying concepts and principles outside the context in which they were first studied, including, where appropriate, the application of those principles in an employment context.	CS1	Apply knowledge and understanding of essential concepts, principles and models within the contemporary global engineering industry.
	AS1	Evidence the ability to show customer relationship management skills and develop appropriate policies and strategies to meet stakeholder expectations.
	AS2	Apply innovative engineering ideas to design and develop new products or services that respond to the changing nature of the engineering industry and the global market.
	AS3	Integrate theory and practice through the investigation, evaluation and development of practices and products in the workplace.
	AS4	Develop outcomes for customers using appropriate practices and data to make justified recommendations.
	CS2	Develop different strategies and methods to show how resources (human, financial, environmental and information) are integrated and effectively managed to successfully meet objectives.
Knowledge of the main methods of enquiry in the subject(s) relevant to the named award, and ability to evaluate critically the appropriateness of different approaches to solving problems in the field of study.	CS3	Critically evaluate current principles and operational practices used within the engineering industry as applied to problem solving.
	CS4	Apply project management skills and techniques for reporting, planning, control and problem solving.
	CS5	Recognise and critically evaluate the professional, economic, social, environmental and ethical issues that influence the sustainable exploitation of people, resources and businesses.
	CS6	Critique a range of engineering information technology systems and operations and their application to maximise and successfully meet strategic objectives.
	KU12	An ability to deploy processes, principles, theories, skills and techniques to analyse, specify, build and evaluate processes and evaluate outcomes.

FHEQ Level 5 descriptor		Engineering HND programme outcome
An understanding of the limits of their knowledge, and how this influences analysis and interpretations based on that knowledge.	TS1	Develop a skill-set to enable the evaluation of appropriate actions taken for problem solving in specific engineering contexts.
	TS2	Develop self-reflection, including self-awareness, to become an effective self-managing student, appreciating the value and importance of the self-reflection process.
	TS3	Undertake independent learning to expand on own skills and delivered content.

Typically, holders of the qualification will be able to:

FHEQ Level 5 descriptor		Engineering HND programme outcomes
Use a range of established techniques to initiate and undertake critical analysis of information, and propose solutions to problems arising from that analysis.	TS4	Competently use digital literacy to access a broad range of research sources, data and information.
	CS7	Interpret, analyse and evaluate a range of engineering data, sources and information to inform evidence-based decision making.
	CS8	Synthesise knowledge and critically evaluate strategies and plans to understand the relationship between theory and real-world engineering situations.
Effectively communicate information, arguments and analysis in a variety of forms to specialist and non-specialist audiences, and deploy key techniques of the discipline effectively.	TS5	Communicate confidently and effectively, both orally and in writing, both internally and externally, with engineering professionals and other stakeholders.
	TS6	Demonstrate strong interpersonal skills, including effective listening and oral communication skills, as well as the associated ability to persuade, present, pitch and negotiate.
Undertake further training, develop existing skills and acquire new competences that will enable them to assume significant responsibility within organisations.	TS7	Identify personal and professional goals for continuing professional development to enhance competence to practice within a chosen engineering field.
	TS8	Take advantage of available pathways for continuing professional development through higher education and professional body qualifications.

Holders will also have:

FHEQ Level 5 descriptor		Engineering HND programme outcomes
The qualities and transferable skills necessary for employment requiring the exercise of personal responsibility and decision making.	TS9	Develop a range of skills to ensure effective team working, project and time management, independent initiatives, organisational competence and problem-solving strategies.
	TS10	Reflect adaptability and flexibility in approach to engineering, showing resilience under pressure and meeting challenging targets within given deadlines.
	TS11	Use quantitative skills to manipulate data and evaluate and verify existing theory.
	CS9	Evaluate the changing needs of the engineering industry and have the confidence to self-evaluate and undertake additional continuing professional development as necessary.
	TS12	Develop emotional intelligence and sensitivity to diversity in relation to people, cultures and environments.
	TS13	Show awareness of current developments within the engineering industry and their impact on employability and continuing professional development.

Appendix 2: HNC/HND Engineering programme outcomes for learners

	Knowledge and understanding											Cognitive skills									Applied skills				Transferable skills											
Unit	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12
1	x			x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x
2	x											x						x					x		x			x								
3	x											x						x					x		x			x								
4	x	x	x	x	x	x	x	x	x	x												x	x		x		x				x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x
6	x	x	x	x	x	x	x		x			x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x						x	x
7	x	x	x								x	x	x					x							x											
8	x																						x													
9	x									x								x					x		x			x								
10	x											x						x					x		x											
11	x																						x													
12	x									x													x		x											
13	x	x	x	x	x	x	x										x	x				x			x							x		x	x	x
14	x											x						x				x			x		x									
15	x					x	x											x								x										
16	x			x	x						x						x	x										x					x			
17	x																	x								x		x					x			
18	x	x	x	x	x	x	x		x	x	x						x	x				x		x	x	x		x					x			

	Knowledge and understanding											Cognitive skills									Applied skills				Transferable skills											
Unit	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12
19	x	x	x		x	x	x		x	x															x							x		x		x
20	x																						x					x				x		x		
21	x											x										x	x											x		
22	x																x											x						x		
23	x	x	x				x				x		x											x	x			x				x		x		x
24	x											x										x	x											x		
25	x																	x																x		
26	x											x										x	x											x		
27	x																							x	x									x		
28	x											x											x											x		
29	x											x						x																x		
30	x	x	x		x		x			x								x					x		x							x	x	x		
31	x											x			x			x					x		x	x		x				x		x		x
32	x	x	x				x				x		x				x	x						x	x			x				x		x		x
33	x	x	x				x				x		x				x	x						x	x			x				x		x		x
34	x	x	x	x	x	x	x					x																						x		x
35	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x	x		x	x	x	x		x		x	x	x	x	x	x
36	x	x	x	x	x	x	x	x		x			x	x	x	x	x		x	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x
37	x						x					x											x											x		x
38	x	x	x			x	x				x														x			x				x		x		

	Knowledge and understanding											Cognitive skills									Applied skills				Transferable skills											
Unit	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12
39	x											x						x					x		x			x						x		
40	x											x						x					x		x			x						x		
41	x																	x										x						x		x
42	x													x								x	x											x		
43	x																	x										x						x		
44	x													x								x	x											x		
45	x						x											x										x						x		
46	x					x																						x						x		
47	x																	x				x	x											x		
48	x											x																x						x		
49	x	x	x		x	x	x												x		x	x	x	x								x		x		x
50	x	x	x	x	x	x	x		x	x	x		x		x				x		x	x	x	x					x	x		x		x		x
51	x	x	x		x	x	x						x		x	x			x				x											x		x
52	x	x	x	x	x	x	x	x	x	x			x	x		x	x		x	x	x		x	x	x	x				x			x	x	x	x
53	x											x						x					x					x						x		
54	x	x	x		x	x	x																x		x									x		
55	x											x		x				x																x		
56	x											x						x					x					x						x		
57	x											x											x					x						x		
58	x											x											x											x		

	Knowledge and understanding											Cognitive skills									Applied skills				Transferable skills											
Unit	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12
59	x											x						x					x					x						x		
60	x											x											x					x						x		
61	x											x													x									x		
62	x											x											x					x						x		
63	x			x							x							x					x											x		
64	x	x	x	x	x	x	x		x	x			x		x			x					x		x	x						x	x	x		
65	x											x																x						x		
66	x	x	x	x	x	x	x						x			x		x	x				x		x			x						x		
67	x	x	x	x																			x		x			x		x				x		
68	x											x						x					x		x			x				x		x		
69	x	x	x									x						x					x		x									x	x	x
70	x				x	x	x					x		x	x			x					x		x							x	x	x		x
71	x	x	x	x	x	x	x				x	x		x	x								x	x	x					x		x	x	x		x
72	x	x	x	x	x	x	x				x		x	x	x	x		x	x		x	x	x	x	x	x	x	x	x	x				x	x	x

Appendix 3: Level 5 Higher National Diploma in Engineering: mapping of transferable employability and academic study skills

Skill sets	**Cognitive skills**							**Intrapersonal skills**				**Interpersonal skills**		
Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan/ Prioritise	Self-Management	Independent Learning	Self-Reflection	Team work	Leadership	Cultural Awareness
1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2	x	x		x	x	x			x	x				
3	x	x		x	x	x			x	x				
4	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x			x
6	x	x	x	x	x	x		x	x	x		x		x
7	x	x	x		x	x	x	x	x	x	x	x		
8	x						x	x	x	x	x			
9	x	x		x	x	x			x	x				
10	x	x	x		x	x		x	x	x				
11	x						x	x	x	x	x			
12	x	x		x	x	x			x	x				
13	x	x	x	x				x	x	x	x	x	x	x
14	x	x		x	x	x			x	x				
15	x						x	x	x	x	x			
16	x	x	x		x	x		x	x	x	x			
17	x	x	x		x	x		x	x	x	x			

Skill sets	**Cognitive skills**							**Intrapersonal skills**				**Interpersonal skills**		
Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan/ Prioritise	Self-Management	Independent Learning	Self-Reflection	Team work	Leadership	Cultural Awareness
18	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
19	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**		
20	**X**	**X**	**X**		**X**	**X**		**X**	**X**	**X**	**X**			
21	**X**	**X**	**X**		**X**	**X**		**X**	**X**	**X**	**X**			
22	**X**	**X**	**X**		**X**	**X**		**X**	**X**	**X**	**X**			
23	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
24	**X**	**X**			**X**	**X**				**X**	**X**			
25	**X**	**X**			**X**	**X**				**X**	**X**			
26	**X**	**X**			**X**	**X**				**X**	**X**			
27	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**			
28	**X**	**X**			**X**	**X**				**X**	**X**			
29	**X**	**X**		**X**	**X**	**X**			**X**	**X**				
30	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
31	**X**	**X**	**X**		**X**	**X**		**X**	**X**	**X**	**X**			
32	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
33	**X**	**X**	**X**		**X**	**X**		**X**	**X**	**X**	**X**	**X**		
34	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
35	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
36	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			
37	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			

Skill sets	Cognitive skills							Intrapersonal skills				Interpersonal skills		
Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan/ Prioritise	Self-Management	Independent Learning	Self-Reflection	Team work	Leadership	Cultural Awareness
38	x	x			x	x		x	x	x	x			
39	x	x	x	x	x	x		x	x	x	x			
40	x	x	x	x	x	x	x	x	x	x	x	x		
41	x	x	x		x	x		x	x	x	x			
42	x	x	x		x	x		x	x	x	x			
43	x	x	x		x	x		x	x	x	x			
44	x	x	x		x	x		x	x	x	x			
45	x	x	x		x	x		x	x	x	x			
46	x	x	x		x	x		x	x	x	x			
47	x	x	x		x	x		x	x	x	x			
48	x	x	x	x	x	x	x	x	x	x	x	x	x	
49	x	x	x	x	x	x	x	x	x	x	x	x	x	
50	x	x	x	x	x	x	x	x	x	x	x	x	x	
51	x	x	x	x	x	x	x	x	x	x	x	x	x	
52	x	x	x	x	x	x	x	x	x	x	x	x	x	
53	x	x	x	x		x	x	x	x	x	x	x	x	
54	x	x	x		x	x		x	x	x	x			
55	x	x	x		x	x		x	x	x	x			
56	x	x	x		x	x		x	x	x	x			
57	x	x			x	x		x	x	x	x			

Skill sets	**Cognitive skills**							**Intrapersonal skills**				**Interpersonal skills**		
Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan/ Prioritise	Self-Management	Independent Learning	Self-Reflection	Team work	Leadership	Cultural Awareness
58	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			
59	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			
60	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			
61	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			
62	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**		
63	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**			
64	**X**	**X**	**X**		**X**	**X**		**X**	**X**	**X**	**X**	**X**		
65	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**		**X**
66	**X**	**X**		**X**	**X**	**X**			**X**	**X**				
67	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**	**X**		
68	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**	**X**		
69	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		
70	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**	**X**		
71	**X**	**X**			**X**	**X**		**X**	**X**	**X**	**X**	**X**		
72	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**			

Appendix 4: Glossary of command verbs used for internally assessed units

This is a summary of the key terms used to define the requirements within units.

Term	Definition
Analyse	Present the outcome of methodical and detailed examination by either: • breaking down a theme, topic or situation to interpret and study the interrelationships between the parts • using information or data to interpret and study key trends and interrelationships. Analysis can be through activity, practice, or written or verbal presentation.
Apply	Put into operation or use. Use relevant skills/knowledge/understanding appropriate to context.
Arrange	Organise or make plans.
Assess	Offer a reasoned judgement of the standard/quality of a situation or a skill informed by relevant facts.
Calculate	Generate a numerical answer with workings shown.
Communicate	Convey ideas or information to others.
Compare	Identify the main factors relating to two or more items/situations or aspects of a subject that is extended to explain the similarities, differences, advantages and disadvantages. This is used to show depth of knowledge through the selection of characteristics.
Compose	Create or make up or form.
Create/Construct	Skills to make or do something, for example a display or set of accounts.
Critically analyse	Separate information into components and identify characteristics with depth to the justification.
Critically evaluate	Make a judgement taking into account different factors and using available knowledge/experience/evidence where the judgement is supported in depth.
Define	State the nature, scope or meaning.
Demonstrate	Show knowledge and understanding.
Describe	Give an account, including all the relevant characteristics, qualities and events.
Design	Plan and present ideas to show the layout/function/workings/object/system/process.

Term	Definition
Determine	To conclude or ascertain by research and calculation.
Develop	Grow or progress a plan, idea, skill or understanding.
Differentiate	Recognise or determine what makes something different.
Discuss	Give an account that addresses a range of ideas and arguments. Consider different aspects of: • a theme or topic • how they interrelate • the extent to which they are important.
Evaluate	Draw on varied information, themes or concepts to consider aspects such as: • strengths or weaknesses • advantages or disadvantages • alternative actions • relevance or significance. Students' inquiries should lead to a supported judgement showing a relationship to context. This will often be in a conclusion. Evidence will often be written but could be through presentation or activity.
Explain	Give an account of the purposes or reasons.
Explore	Skills and/or knowledge involving practical research or testing.
Identify	Indicate the main features or purpose of something by recognising it and/or being able to discern and understand facts or qualities.
Illustrate	Make clear using examples or provide diagrams.
Indicate	Point out, show.
Interpret	State the meaning, purpose or qualities of something through the use of images, words or other expression.
Investigate	Conduct an inquiry or study into something to discover and examine facts and information.
Justify	Students give reasons or evidence to: • support an opinion • show something to be right or reasonable.
Outline	Set out the main points/characteristics.
Plan	Consider, set out and communicate what is to be done.
Produce	Bring into existence.
Reconstruct	Assemble again/reorganise/form an impression.

Term	Definition
Report	Adhere to protocols, codes and conventions where findings or judgements are set down in an objective way.
Review	Make a formal assessment of work produced. The assessment allows students to: • appraise existing information or prior events • reconsider information with the intention of making changes, if necessary.
Show how	Demonstrate the application of certain methods/theories/concepts.
Stage and manage	Organisation and management skills, for example running an event or a business pitch.
State	Express.
Suggest	Give possible alternatives, produce an idea, put forward, e.g. an idea or plan, for consideration.
Undertake/ Carry out	Use a range of skills to perform a task, research or activity.

This is a key summary of the types of evidence used for BTEC Higher Nationals.

Type of evidence	Definition
Case study	A specific example all students must select and to which they must apply knowledge.
Project	A large-scale activity requiring self-direction or selection of outcome, planning, research, exploration, outcome and review.
Independent research	An analysis of substantive research organised by the student from secondary sources and, if applicable, primary sources.
Written task or report	Individual completion of a task in a work-related format, e.g. a report, marketing communication, set of instructions, giving information.
Simulated activity/ role play	A multi-faceted activity mimicking realistic work situations.
Team task	Students work together to show skills in defining and structuring activity as a team.
Presentation	Oral or through demonstration.
Production of plan/business plan	Students produce a plan as an outcome related to a given or limited task.
Reflective journal	Completion of a journal from work experience, detailing skills acquired for employability.
Poster/leaflet	Documents providing well-presented information for a given purpose.

Appendix 5: Assessment Methods and Techniques for Higher Nationals

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Academic graphic display	This technique asks students to create documents providing well-presented information for a given purpose. Could be hard or soft copy.	Creativity	Formative
		Written Communication	Summative
		Information and Communications Technology	
		Literacy	
Case Study	This technique present students with a specific example to which they must select and apply knowledge.	Reasoning	Formative
		Critical Thinking	Summative
		Analysis	
Discussion Forum	This technique allows students to express their understanding and perceptions about topics and questions presented in the class or digitally, for example online groups, blogs.	Oral/written Communication	Formative
		Appreciation of Diversity	
		Critical Thinking and Reasoning	
		Argumentation	
Examination	This technique covers all assessment that needs to be done within a centre-specified time constrained period on-site. Some units may be more suited to an exam-based assessment approach, to appropriately prepare students for further study such as progression on to Level 6 programmes or to meet professional recognition requirements.	Reasoning	Summative
		Analysis	
		Written Communication	
		Critical Thinking	
		Interpretation	
Independent Research	This technique is an analysis of research organised by the student from secondary sources and, if applicable, primary sources.	Information and Communications Technology	Formative
		Literacy	
		Analysis	
Oral/Viva	This technique asks students to display their knowledge of the subject via questioning.	Oral Communication	Summative
		Critical Thinking	
		Reasoning	

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Peer Review	This technique asks students to provide feedback on each other's performance. This feedback can be collated for development purposes.	Teamwork	Formative
		Negotiation	Summative
		Collaboration	
Presentation	This technique asks students to deliver a project orally or through demonstration.	Oral Communication	Formative
		Creativity	Summative
		Critical Thinking	
		Reasoning	
Production of an Artefact/Performance or Portfolio	This technique requires students to demonstrate that they have mastered skills and competencies by producing something. Some examples are project plans, using a piece of equipment or a technique, building models, developing, interpreting, and using maps.	Creativity	Summative
		Interpretation	
		Written and oral Communication	
		Decision-making	
		Initiative	
		Information and Communications	
		Technology	
		Literacy, etc.	
Project	This technique is a large-scale activity requiring self-direction, planning, research, exploration, outcome and review.	Written Communication	Summative
		Information Literacy	
		Creativity	
		Initiative	
Role Playing	This technique is a type of case study, in which there is an explicit situation established, with students playing specific roles, understanding what they would say or do in that situation.	Written and Oral Communication	Formative
		Leadership	
		Information Literacy	
		Creativity	
		Initiative	

Assessment Technique	**Description**	**Transferable Skills Development**	**Formative or Summative**
Self-reflection	This technique asks students to reflect on their performance, for example, to write statements of their personal goals for the course at the beginning of the course, what they have learned at the end of the course and their assessment of their performance and contribution; completion of a reflective journal from work experience, detailing skills acquired for employability.	Self-reflection Written Communication Initiative Decision-making Critical Thinking	Summative
Simulated Activity	This technique is a multi-faceted activity based on realistic work situations.	Self-reflection Critical Thinking Initiative Decision-making Written Communication	Formative Summative
Team Assessment	This technique asks students to work together to show skills in defining and structuring an activity as a team. All team assessment should be distributed equally, each of the group members performing their role, and then the team collates the outcomes, and submits it as a single piece of work.	Collaboration Teamwork Leadership Negotiation Written and Oral Communication	Formative Summative
Time-constrained Assessment	This technique covers all assessment that needs to be done within a centre-specified time constrained period on-site.	Reasoning Analysis Critical thinking Interpretation Written Communication	Summative
Top Ten	This technique asks students to create a 'top ten' list of key concepts presented in the assigned reading list.	Teamwork Creativity Analysis Collaboration	Formative

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Written Task or Report	This technique asks students to complete an assignment in a structured written format, for example, a project plan, a report, marketing communication, set of instructions, giving information.	Reasoning	Summative
		Analysis	
		Written Communication	
		Critical Thinking	
		Interpretation	

Appendix 6: Recognition of Prior Learning

QCF Pearson BTEC Level 4 Higher National Certificate in Engineering unit content mapped to the Level 4 units available in the Pearson BTEC Higher National Engineering programmes (RQF)

HNCs in Engineering: Unit Mapping Overview

This mapping document is designed to support centres who wish to recognise student achievement in older QCF Higher Nationals within the new RQF suites. The document demonstrates where content is covered in the new suite, and where there is new content to cover to ensure full coverage of learning outcomes.

P – Partial mapping (some topics from the old unit appear in the new unit)

X – Full mapping + new (all the topics from the old unit appear in the new unit, but new unit also contains new topic(s))

N – New unit

Unit no.	Unit title New RQF HN programme	Maps to unit number on existing QCF HN programme	Level of similarity between units
1	Engineering Design	8	P
2	Engineering Mathematics	1	P
3	Engineering Science	2	X
4	Managing a Professional Engineering Project		New Unit
5	Renewable Energy		New Unit
6	Mechatronics	57	P
7	Machining and Metal Forming Processes	10	P
8	Mechanical Principles	4	P
9	Materials, Properties and Testing	21	P
10	Mechanical Workshop Practices	13	P
11	Fluid Mechanics	41	X
12	Engineering Management	38	P
13	Fundamentals of Thermodynamics and Heat Engines	61	P
14	Production Engineering for Manufacture	9	P
15	Automation, Robotics and PLCs	22 32	P P
16	Instrumentation and Control Systems	55	P

Unit no.	Unit title New RQF HN programme	Maps to unit number on existing QCF HN programme	Level of similarity between units
17	Quality and Process Improvement	20 30 36	P P P
18	Maintenance Engineering	43 44 54	P P P
19	Electrical and Electronic Principles	5	X
20	Digital Principles		N
21	Electrical Machines	65	P
22	Electronic Circuits and Devices	39	P
23	Computer Aided Design and Manufacture (CAD/CAM)	19	X
24	Aircraft Aerodynamics	83	X
25	Aircraft Electrical Power & Distribution Systems	82	
26	Airframe Mechanical Systems		N
27	Composite Materials for Aerospace Applications		N
28	Turbine Rotary Wing Mechanical and Flight Systems		N
29	Electro, Pneumatic and Hydraulic Systems	24	P
30	Operations and Plant Managements	45 46 47	P P P
31	Electrical Systems and Fault Finding		N
32	CAD for Maintenance Engineers		N
73	Materials Engineering with Polymers	155	X
74	Polymer Manufacturing Processes	156	X
75	Industry 4.0		N
76	Introduction to Professional Engineering Management		N
77	Industrial Robots		N
78	Programmable Logic Controllers		N
79	Computer Aided Design (CAD) for		N

Unit no.	Unit title New RQF HN programme	Maps to unit number on existing QCF HN programme	Level of similarity between units
	Engineering		
80	Welding Technology	154	X
81	Welding Inspection	153	X

HNCs in Engineering: Unit Mapping Depth

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
1	Engineering Design	8	Engineering Design	Unit 8: LO1 Unit 8: LO2 Unit 8: LO3 No Match	Unit 1: LO1 Unit 1: LO2 Unit 1: LO3 Unit 1: LO4 No match
2	Engineering Mathematics	1	Analytical Methods for Engineers	Unit 1: LO2 Unit 1: LO3 Unit 1: LO4	Unit 2: LO1 No match Unit 2: LO3 Unit 2: LO4 Unit 2: LO2
3	Engineering Science	2	Engineering Science	Unit 2: LO1/2 Unit 2: LO3/4	Unit 3: LO2 Unit 3: LO4 Unit 3: LO1 No match Unit 3: LO3 No match
4	Managing a Professional Engineering Project		New unit, no equivalent		
5	Renewable Energy		New unit, no equivalent		
6	Mechatronics	57	Mechatronics	Unit 57: LO1 Unit 57: LO3	Unit 6: LO1 Unit 6: LO3 No match Unit 6: LO2 Unit 6: LO4 No match
7	Machining and Metal Forming Processes	10	Manufacturing Process	Unit 10: LO1 Unit 10: LO2	Unit 7: LO1 Unit 7: LO4 Unit 7: LO2 No match Unit 7: LO3 No match
8	Mechanical Principles	4	Mechanical Principles	Unit 4: LO2 Unit 4: LO3 Unit 4: LO4	Unit 8: LO1 Unit 8: LO2 No match Unit 8: LO3/4 Unit 8: LO3/4
9	Materials, Properties and Testing	21	Materials Engineering	Unit 21: LO1 Unit 21: LO2 Unit 21: LO3 Unit 21: LO4	Unit 9: LO2 No match Unit 9: LO3 Unit 9: LO1 Unit 9: LO4

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
10	Mechanical Workshop Practices	10	Manufacturing Process	Unit 10: LO1	Unit 10: LO2 Unit 10: LO1 No match Unit 10: LO3 No match Unit 10: LO4 No match
11	Fluid Mechanics	41	Fluid Mechanics	Unit 41: LO1 Unit 41: LO2 Unit 41: LO3 Unit 41: LO4	Unit 11: LO1 Unit 11: LO2 Unit 11: LO3 Unit 11: LO4
12	Engineering Management	38	Managing People in Engineering	Unit 38: LO1/2 Unit 38: LO3	Unit 12: LO1 Unit 12: LO2 Unit 12: LO3 No match Unit 12: LO4 No match
13	Fundamentals of Thermodynamics and Heat Engines	61	Engineering Thermodynamics	Unit 61: LO1 Unit 61: LO2 Unit 61: LO4	Unit 13: LO1 Unit 13: LO4 Unit 13: LO3 No match Unit 13: LO2
14	Production Engineering for Manufacture	9	Manufacturing Planning and Scheduling Principles	Unit 9: LO1 Unit 9: LO4	Unit 14: LO1 Unit 14: LO2 Unit 14: LO3 No match Unit 14: LO4 No match
15	Automation, Robotics and PLCs	22 & 32	Programmable Logic Controllers (22) and Industrial Robot Technology (32)	Unit 22: LO1 Unit 32: LO2 Unit 22: LO2 Unit 32: LO3	Unit 15: LO1 Unit 15: LO2 Unit 15: LO3 Unit 15: LO4
16	Instrumentation and Control Systems	55	Instrumentation and Control Systems	Unit 55: LO1 Unit 55: LO2	Unit 16: LO1 Unit 16: LO1 & LO2 Unit 16: LO 3 No match Unit 16: LO4 No match:

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
17	Quality and Process Improvement	20, 30 & 36	Quality & Business Improvement (20), Quality Assurance & Management (30) and Statistical Process Control (36)	Unit 36: LO1 Unit 20: LO2 & Unit 30: LO2	Unit 17: LO1 Unit 17: LO2 No match Unit 17: LO3 No match Unit 17: LO4
18	Maintenance Engineering	44, 45	Plant Maintenance and Decommissioning (44), Plant Operations and Performance (45)	Unit 45: LO 1/2 Unit 44: LO1/2 Unit 44: LO3	Unit 18: LO1 Unit 18: LO2 Unit 18: LO3 No Match Unit 18: LO4
19	Electrical and Electronic Principles	5	Electrical and Electronic Principles	Unit 5: LO3	Unit 19: LO1 No match Unit 19: LO2 Unit 19: LO3 No match Unit 19: LO4 No match
20	Digital Principles		New unit, no equivalent		
21	Electrical Machines	65	Utilisation of Electrical Energy	Unit 65: LO1 Unit 65: LO5	Unit 21: LO1 Unit 21: LO2 Unit 21: LO3 No Match Unit 21: LO4 No match
22	Electronic Circuits and Devices	39	Electronic Principles	Unit 39: LO2 Unit 39: LO3 Unit 39: LO4	Unit 22: LO1 Unit 22: LO2 Unit 22: LO3 Unit 22: LO4 No match
23	Computer Aided Design and Manufacture (CAD/ CAM)	19	Computer-aided Design and Manufacture	Unit 19: LO1 Unit 19: LO2 Unit 19: LO3	Unit 23: LO1 Unit 23: LO2 Unit 23: LO3 Unit 23: LO4 No match
24	Aircraft Aerodynamics	83	Aerodynamic Principles and Aircraft Design	Unit 83: LO1 Unit 83: LO2 Unit 83: LO3 Unit 83: LO4	Unit 24: LO1 Unit 24: LO2 Unit 24: LO3 Unit 24: LO4

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
25	Aircraft Electrical Power & Distribution Systems	82	Aircraft Systems Principles and Applications	Unit 82: LO2	Unit 25: LO1 No match Unit 25: LO2 Unit 25: LO3 No match Unit 25: LO4 No match
26	Airframe Mechanical Systems		New unit, no equivalent		
27	Composite Materials for Aerospace Applications		New unit, no equivalent		
28	Turbine Rotary Wing Mechanical and Flight Systems		New unit, no equivalent		
29	Electro, Pneumatic and Hydraulic Systems	24	Applications of Pneumatics and Hydraulics	Unit 24: LO1 Unit 24: LO3	Unit 29: LO1 No match Unit 29: LO2 Unit 29: LO3 Unit 29: LO4 No match
30	Operations and Plant Managements		New unit, no equivalent		
31	Electrical Systems and Fault Finding		New unit no equivalent		
32	CAD for Maintenance Engineers		New unit, no equivalent		
33	Fundamentals of Nuclear Power Engineering		New unit no equivalent		
73	Materials Engineering with Polymers	155	Materials Engineering with Polymers	Unit 155: LO1 Unit 155: LO2 Unit 155: LO3 Unit 155: LO4	Unit 73: LO1 Unit 73: LO2 Unit 73: LO3 Unit 73: LO4
74	Polymer Manufacturing Processes	156	Polymer Manufacturing Processes	Unit 156: LO1 Unit 156: LO2 Unit 156: LO3 Unit 156: LO4	Unit 74: LO1 Unit 74: LO2 Unit 74: LO3 Unit 74: LO4

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
75	Industry 4.0		New unit, no equivalent		
76	Introduction to Professional Engineering Management		New unit no equivalent		
77	Industrial Robots		New unit, no equivalent		
78	Programmable Logic Controllers		New unit no equivalent		
79	Computer Aided Design (CAD) for Engineering		New unit, no equivalent		
80	Welding Technology	154	Welding Technologies	Unit 154: LO1 Unit 154: LO2 Unit 154: LO3 Unit 154: LO4	Unit 80: LO1 Unit 80: LO2 Unit 80: LO3 Unit 80: LO4
81	Welding Inspection	153	Welding Inspection	Unit 153: LO1 Unit 153: LO2 Unit 153: LO3 Unit 153: LO4	Unit 81: LO1 Unit 81: LO2 Unit 81: LO3 Unit 81: LO4

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