Pearson
Higher National in
Manufacturing Operations

Specification

First Teaching from January 2019
First Certification from 2020
Issue 2

Level 4
BTEC Higher National Certificate

Level 5
BTEC Higher National Diploma

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.

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Summary of changes in Pearson BTEC Higher Nationals in Manufacturing Operations Engineering Issue 2

Summary of changes made between previous issue and this current issue	**Page number**
Unit 5 Corrected LO2 – removed the following '~~*by using appropriate computer software packag*~~es' 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	90-95
Unit 23 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	225 - 231

Unit 24 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	232 - 237

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 one of 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 Certificate in Manufacturing Operations, we collaborated with a wide range of students, employers, higher education providers, colleges and subject experts, to ensure that the new qualification meets their needs and expectations. There is now a greater emphasis on employer engagement and work readiness.

The new BTEC Higher National Certificate in Manufacturing Operations is designed to reflect this increasing need for high quality professional and technical education at Level 4. The qualification provides students with a clear pathway to employment, appropriate support during employment and a recognised progression route to gain further learning.

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 this qualification. 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 a qualification 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 4 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 means that students wishing to progress to Level 5 and 6 study should feel better prepared. The Pearson BTEC Higher Nationals address these various requirements by providing:

- A range of core and optional 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.
- Assessments and projects chosen to help students progress to the next stage. 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 which is aligned with the Framework for Higher Education Qualifications (FHEQ).

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 Manufacturing Operations

1.5 Qualification codes

Regulated Qualifications Framework (RQF) Qualification number:

- Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations 603/3938/X

1.6 Awarding organisation

Pearson Education Ltd

1.7 Key features

Pearson BTEC Higher National Certificate in Manufacturing Operations offers:

- 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 core of learning, required by all working within manufacturing operations
- 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)
- A varied approach to assessment that supports progression to Level 5 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 qualification.
- A programme that is intended to span all manufacturing operations, with a particular focus on:
    - High-volume manufacturing or advanced manufacturing processes in which large volumes of products are made in assembly, moulding, metal processing, chemical processing or similar processing
    - Engineering operations or low-volume manufacturing processes in which lower volumes of products are made in a bespoke or workshop-type environment
    - The food, textiles and automotive sectors, to which the qualification is especially relevant, although the qualification is not limited to these sectors.
- Supports in delivering some of the technical knowledge content of the Process Leader Apprenticeship Standard.

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 Benchmarks Statements. This qualification is part of the UK Regulated Qualifications Framework (RQF).

1.8 Collaborative development

Students completing their Pearson BTEC Higher National Certificate in Manufacturing Operations will be working within a manufacturing environment and progress to a more senior role or progress to a higher level of study. Therefore, it was essential that we developed this qualification 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, and other individuals who have generously shared their time and expertise to help us develop this new qualification.

2 Programme purpose and objectives

2.1 Purpose of the Pearson BTEC Higher National Certificate in Manufacturing Operations

The purpose of Pearson BTEC Higher National Certificate in Manufacturing Operations is to develop students as professional, self-reflecting individuals who are able to meet the demands of employers in the rapidly evolving manufacturing sector and adapt to a constantly changing world. The qualification also aims to widen access to higher education and enhance the career prospects of those who undertake it.

2.2 Objectives of the Pearson BTEC Higher National Certificate in Manufacturing Operations

The objectives of the Pearson BTEC Higher National Certificate in Manufacturing Operations are as follows:

- To provide students with the core knowledge, skills and techniques that all engineers/process leaders within manufacturing operations require to achieve high performance in this sector
- To build a body of specialist knowledge, skills and techniques in order to be successful in a range of careers in manufacturing
- 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 within which they operate
- To understand the responsibilities of the engineer/process leader within society, and equip them to work with integrity, regard for cost, sustainability and the rapid rate of change experienced in world-class engineering/manufacturing
- To provide opportunities for students to enter, or progress in, employment within the manufacturing sector, or progress to higher education qualifications such as degrees and honours degree in engineering or a closely related area, by balancing employability skills with academic attainment
- To allow flexibility of study and to meet local or specialist needs.

We aim to meet these objectives by:

- Providing a thorough grounding in manufacturing principles at Level 4 and providing a progression opportunity to Level 5 Higher National Diploma study. Students who wish to progress to the Level 5 Pearson BTEC Higher National Diploma in Engineering should have studied the following units at Level 4:
- Unit 5: Engineering Maths

  Unit 23: Engineering Design

  Unit 24: Engineering Science

  Unit 25: Managing a Professional Engineering Project (Pearson-set)
- Equipping individuals with the essential qualities, including integrity, regard for cost and sustainability, as they apply to a range of roles and responsibilities within the manufacturing operations 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 4.
- Supporting a range of study modes and timeframes for completion of the qualification.

Who is this qualification for?

The Pearson BTEC Higher National Certificate in Manufacturing Operations is aimed at students wanting to continue their education through applied learning/progress in employment. The Higher National Certificate provides a wide-ranging study of the manufacturing sector and is designed for students who wish to pursue a career in manufacturing. In addition to the skills, knowledge and techniques that underpin the qualification, the Pearson BTEC Higher National Certificate in Manufacturing Operations gives 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 Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations

The Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations offers students a broad introduction to the subject area via a mandatory core of learning, while allowing for the acquisition of some sector-specific skills and experience through the specialist units in each pathway, with the opportunity to pursue a particular interest through the appropriate selection of optional units. This effectively builds underpinning core skills. Students will gain a wide range of sector knowledge tied to practical skills gained in research, self-study, directed study and workplace activities.

Graduates successfully completing the Higher National Certificate will be able to demonstrate a sound knowledge of the basic concepts of manufacturing operations. 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/process leader, for cost and for the importance of protecting and sustaining the environment.

2.5 What could this qualification lead to?

The Level 4 Higher National Certificate provides a solid grounding in manufacturing operations, which students can build on should they decide to continue their studies beyond the Certificate stage. On successful completion of the Level 4 Higher National Certificate, students can develop their careers in the manufacturing sector through:

- Progressing to the Level 5 Higher National Diploma in Engineering
- Entering employment
- Continuing existing employment
- Committing to Continuing Professional Development (CPD)
- Progressing to university.

Students should always check the entry requirements for degree programmes at specific higher education providers.

The skills offered as part of the Pearson BTEC Higher National Certificate can provide graduates with the opportunity to work in many different areas of manufacturing, for example of role of Process Leader.

2.6 Use of maths and English within the curriculum

Those working within the manufacturing sector cannot just rely on their technical skills and must ensure they develop all relevant employability skills to increase employment opportunities. For example, they will be required to communicate appropriately with stakeholders throughout their career, so 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 this qualification in accordance with industry requirements and below are some examples of how these skills are developed in the BTEC Higher National curriculum:

- written reports
- formal presentations
- informal conversations
- use of professional, sector-specific language
- use of 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 manufacturing require high-level maths skills and we strongly recommend all students complete diagnostic maths assessments preferably before beginning a Higher National course, as well as having a grade of A* to C 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 a high level of maths within the curriculum. It is vital that all students taking a Pearson BTEC Higher National Certificate in Manufacturing Operations 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.

The qualification has been designed to enable Centres to select at least one specialist maths unit:

Unit 3: Statistical Process Control

Unit 4: Manufacturing Operations Mathematics

Unit 5: Engineering Maths

These specialist maths units are intended to complement the core and optional units available and provide the opportunity to specialise.

Students who wish to progress to the Pearson BTEC Higher National Diploma in Engineering must study Unit 5: Engineering Maths.

2.7 How the Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations provides both transferable employability skills and academic study skills

Students need both good qualifications and employability skills to enhance their career prospects and personal development. The Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations certificate embeds, throughout the programme, the development of the 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
- **Intra-personal 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.

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, the BTEC Higher National Certificate provides 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 higher education-relevant transferable and academic study skills, available in *Appendix 2*.

3 Planning your programme

3.1 Delivering the Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations

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 specialist and 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 in order 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:

- Grade A* to C and/or 9 to 4 in GCSE Maths, or equivalent (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 relevant GCE Advanced Level 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 any of the above.

Centres may wish to consider applicants' prior learning when considering their acceptance on a 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. In order 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 the Apprenticeship Standard for the role of Process Leader.

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 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 you are still dissatisfied with the final outcome of your appeal you 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, 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 M2b* form (downloadable from 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 Assurances 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.

BTEC Higher National Certificate consists of core, specialist and optional units:

- Core units are mandatory
- At least one specialist unit must be selected
- Required combinations of units are clearly set out in the table below.

All units are 15 credits in value. 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 TQT of 150 hours and 60 hours of Guided Learning.

Total Qualification Time (TQT) Higher National Certificate (HNC) = 1,200 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 and observed assessment and observed work-based practice.

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

Some examples of activities which can contribute to GL 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.

Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations

- 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 on the Pearson website.

The unit combinations are as follows:

Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations (120 credits)		**Unit credit**	**Level**
Core unit *Mandatory*	**1: Manufacturing Processes**	15	4
Core unit *Mandatory*	**2: Manufacturing Planning and Scheduling Principles**	15	4
And, at least one from the following list of specialist units			
Specialist unit *Optional*	**3: Statistical Process Control**	15	4
Specialist unit *Optional*	**4: Manufacturing Operations Mathematics**	15	4
Specialist unit *Optional*	**5: Engineering Maths***	15	4
Plus optional units from the following list			
Optional unit	**6: Material Handling Systems**	15	4
Optional unit	**7: Workplace Study and Ergonomics**	15	4
Optional unit	**8: Business Improvement Techniques for Engineers**	15	4
Optional unit	**9: Dimensional Control of Complex Assemblies**	15	4
Optional unit	**10: Industry 4.0**	15	4
Optional unit	**11: Lean Techniques for Manufacturing Operations**	15	4
Optional unit	**12: Monitoring and Fault Diagnosis of Engineering Systems**	15	4
Optional unit	**13: Sustainability and the Environment in the Manufacturing Industry**	15	4
Optional unit	**14: Introduction to Plant Commissioning and Decommissioning**	15	4
Optional unit	**15: Creating and Managing Projects in Manufacturing Operations**	15	4
Optional unit	**16: Introduction to Professional Engineering Management**	15	4
Optional unit	**17: Industrial Robots**	15	4

Optional unit	**18: Programmable Logic Controllers (PLCs)**	15	4
Optional unit	**19: Engineering Plant Operation and Maintenance**	15	4
Optional unit	**20: Mechatronic Systems in Manufacturing**	15	4
Optional unit	**21: Properties and Applications of Materials and Emerging Materials PreProduction**	15	4
Optional unit	**22: Introduction to Manufacturing Systems Engineering**	15	4
Optional unit	**23: Engineering Design***	15	4
Optional unit	**24: Engineering Science***	15	4
Optional unit	**25: Managing a Professional Engineering Project (Pearson-set)***	15	4
Optional unit	**26: Materials, Properties and Testing**	15	4
Optional unit	**27: Production Engineering for Manufacture**	15	4
Optional unit	**28: Instrumentation and Control Systems**	15	4
Optional unit	**29: Quality and Process Improvement**	15	4
Optional unit	**30: Maintenance Engineering**	15	4
Optional unit	**31: Computer-Aided Design and Manufacture (CAD/CAM)**	15	4
Optional unit	**32: Materials Engineering with Polymers**	15	4

*Selection of this unit will enable the student to progress to the Pearson BTEC Higher National Diploma in Engineering.

Units selected from the Pearson BTEC Higher Nationals in Engineering

The following units have been selected from the Pearson BTEC Higher Nationals in Engineering. The table provides details of the unit numbers within this qualification and also the Pearson BTEC Higher Nationals in Engineering.

Unit Title	**Unit Number**	
	HNC in Manufacturing Operations	**HN in Engineering**
Engineering Design*	23	1
Engineering maths*	5	2
Engineering Science*	24	3
Managing a Professional Engineering Project*	25	4
Material Handling Systems	26	9
Production Engineering for Manufacture	27	14
Instrumentation and Control Systems	28	16
Quality and Process Improvement	29	17
Maintenance Engineering	30	18
Computer-Aided Design and Manufacture (CAD/CAM)	31	23
Materials Engineering with Polymers	32	73

*Selection of this unit will enable the student to progress to the Pearson BTEC Higher National Diploma in Engineering.

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 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 needs 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.** 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 an 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) that 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.

4.3 Pearson-set Assignments

Unit 25: Managing a Professional Engineering Project is the Pearson-set unit at Level 4 in the Pearson BTEC Higher Nationals in Engineering. Although, not a core unit in this qualification, if this unit is selected, it is recommended the Pearson-set assignment is delivered, particularly if the student wishes to progress to the Pearson BTEC Higher National Diploma in Engineering.

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.

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 on the Pearson website. 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 Unit descriptor example

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 code is the Ofqual unit designation

The unit title tells your students what the unit is about - in this case "Individual Project". 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.

There are three unit types: Core units (which students have to complete to achieve either at 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.

Unit 1: Individual Project

Unit code	**R/615/1387**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

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

Introduction

The ability to define, plan and undertake a project is a critical set of s
various roles within the construction industry. Identifying appropriate
and analysing this, to formulate clear results or recommendations, is
underpin many of the processes that inform construction projects.

The aim of this unit is to support students in using and applying the k
skills they have developed through other areas of their studies to con
present an individual project. In addition, this unit will provide studen
study skills that will support them in further study.

Students will be able to identify, define, plan, develop and execute a
project by working through a clear process. They will develop a proje
outlining a problem that requires a solution, as well as a project spec
specific requirements of which the final outcome must meet. They wi
problem, undertaking a feasibility study, and consider a range of pot
using critical analysis and evaluation techniques to test, select and c
their preferred solution. Students will provide a work and time manag
keeping a diary of all activities, reflecting on their process and their l
throughout the project.

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

The credit value is related to the Total Qualification Time (TQT) and Unit Learning Hours ULH), and is easy to a calculate. 1 credit equals 10 ULH. So, 15 credits equals 150 ULH. To complete a Higher National Certificate or Diploma students are expected to achieve the appropriate number of credits.

Learning Outcomes

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

1. Formulate a project that will provide a solution to an identified problem.
2. Manage a project within agreed timescales and specification; documenting the process throughout.
3. Evaluate potential project management solutions.
4. Produce a project report and deliver a presentation of the final project outcomes.

There are usually four Learning Outcomes for each unit. 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

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's Learning Outcomes with the student's work. This assignment may be graded at 'Pass', 'Merit' or 'Distinction' level, depending on the quality of the student's work.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Formulate a project that will provide a solution to an identified problem		
P1 Select an appropriate construction-based project, giving reasons for your choice. **P2** Identify the main components of a project specification.	**M1** Explain why the project specification is of fundamental importance to a successful project outcome.	**LO1 & 2** **D1** Evaluate the relationship between project identification, feasibility and project planning, with consideration of the impact of project scope on time and resources.
LO2 Manage a project within agreed timescales and specification, documenting the process throughout		
P3 Identify potential resources, costs and timescales. **P4** Describe a range of appropriate techniques for generating realistic potential solutions.	**M2** Prepare and update a project management plan, using standard systems of time and resource tracking.	
LO3 Evaluate potential project management solutions		
P5 Explore project management strategies to determine suitability for a given project. **P6** Justify the selection of your preferred solution, making reference to your initial project specification.	**M3** Compare the outcomes of your initial planned resources, timescales and costs against actual outcomes.	**LO3 & 4** **D2** Appraise your own performance in managing the project; draw conclusions and make recommendations that would further improve your performance in the future.
LO4 Produce a project report and deliver a presentation of the final project outcomes		
P7 Produce a written report identifying each stage of the project. **P8** Utilise appropriate forms of referencing and citation in the preparation of a written report. **P9** Prepare a presentation of your final project outcomes, utilising industry standard software.	**M4** Present your final project outcomes and recommendations to a selected audience.	

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

Recommended Resources

Textbooks

BALDWIN, A. (2014) *Handbook for Construction Planning and Scheduling*. London: Wiley-Blackwell.

BUSSEY, P. (2015) CDM 2015: *A Practical Guide for Architects and Designers.* London: RIBA.

CIOB (2010) *Guide to Good Practice in the Management of Time in Complex Projects*. London: Chartered Institute of Building.

GOETSCH, D. L. (2011) *Construction Safety & Health*. London: Pearson.

KELLY, J. and MALE, S. (1992) *Value Management in Design and Construction: The Economic Management of Project*. London: Taylor & Francis.

POTTS, K. and ANKRAH, N. (2014) *Construction Cost Management: Learning from Case Studies*. London: Routledge.

LAWSON, B. (2005) *How Designers Think: The Design Process Demystified*. London: Routledge.

WYATT, D. (2007) *Construction Specifications: Principles and Applications*. New York: Delmar.

Links

This unit links to the following related units:

Unit 1: Independent Project

Unit 5: Legal & Statutory Responsibilities in Construction

Unit 6: Construction Information (Drawing, Detailing, Specification)

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

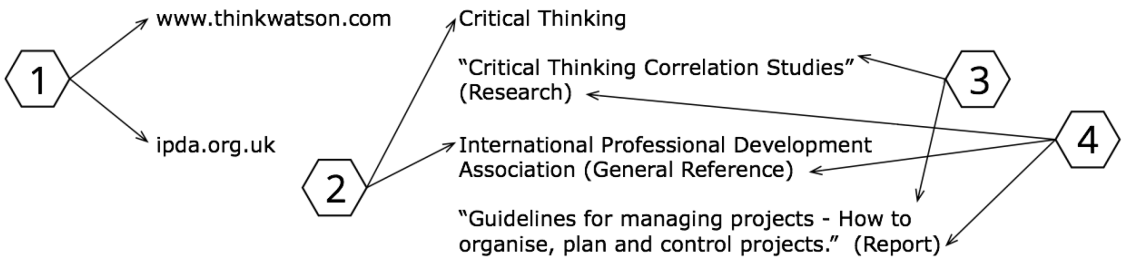
3 The name of the section or element of the website where the resource can be found

4 The type of resource it is. This could be one of the following –

- Research
- General Reference
- Tutorials
- Training
- E-Books
- Report
- Article
- Datasets
- Development Tool
- Discussion Forum.

Some examples from computing units have been shown below:

Websites



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 Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations will have the attributes, skills, principles and behaviours that will enable them to make a valuable contribution to local, national and international manufacturing.

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 counsel 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 Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations on Ofqual's qualification framework (RQF) and benchmarking to the Framework for Higher Education Qualifications (FHEQ). The Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations is aligned with Level 4 of both frameworks. This means that the HNC has the same level of demand and expectations as the first year of a degree programme.

Centres are expected to provide a broadly similar experience for students to that which they would have if they had attended a similar programme at a university. This could mean:

- Providing access to a library which has, as a minimum, available copies (physically and/or electronically) of all required reading material
- Access to research papers and journals
- Utilising 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. This is 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 Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations. 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 manufacturing facilities
- Inviting members of the local manufacturing community to present guest lectures
- Using practising engineers/process leaders 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 on to 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 on-going 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. 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, Units 1: Manufacturing Processes and 2: Manufacturing Planning and Scheduling Principles could be the first two 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 chose 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 for 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 the 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, for example, 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/process leaders 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 on-going 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 assessment 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 contribute 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 that 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) that is (are) 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 utilise 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

The Pearson BTEC Leve 4 Higher National Certificate in Manufacturing Operations is assessed using a combination of internally assessed Centre-devised internal assignments (which are set and marked by Centres) and internally assessed Pearson-set assignment, if Unit 25: Managing a Professional Engineering Project is selected (which is set by Pearson and marked by Centres).

The purpose and rationale of having a Pearson-set unit 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 brief 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 assignment. 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.

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/manufacturing 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 Pass criterion requires the student to 'explain', then to satisfy the Merit criterion a student will need to cover both 'explain' and 'analyse'. 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 annually with Pearson 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 so that we can monitor 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 that 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 that you must follow.

Pearson provide Example Assessment Briefs for each unit to support you in developing and designing your own assessments, if you wish to do so 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 that they can provide all the required evidence for assessment, and that 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 learnt.

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 students 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 verified 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 grade; 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 grades 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

When a student who has failed the first assessment opportunity and, following a resubmission opportunity, has still failed to achieve a Pass for that unit specification, a decision can be made to permit a repeat of the unit, at the discretion of the Centre and Assessment Board, subject to these criteria:

- 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

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

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, based on unit achievement.

All units in valid combination must have been attempted. The conditions of award and the compensation provisions will apply as outlined above. All 120 credits count in calculating the grade.

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

7 Quality Assurance

Pearson's Quality Assurance system for all Pearson BTEC Higher National programmes is benchmarked to Level 4 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 either to quality assure its programme delivery or its assessment standards.

7.2 Monitoring of internal Centre systems

Centres will be required to demonstrate on-going 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 on-going 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 on-going effectiveness of such systems. Where system failures are identified, sanctions (appropriate to the nature of the problem) will be applied, in order 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 of the Quality Assurance Agency (QAA) 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 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 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.
- There must be systems 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 qualification regulators' 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 that 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 Adjustment* and *Special Consideration in Vocational Internally Assessed Units*. See the support section our website for both documents (http://qualifications.pearson.com/).

10 Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations Units

Unit 1: Manufacturing Processes

Unit code	**F/617/3918**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

Cars, food and drink, textiles, electronic and household appliances are manufactured using a variety of processes and materials. These processes have several interdependent stages, and producing finished high quality products at competitive prices requires that each part of the process operates efficiently.

This unit introduces students to the various processes and technologies used in the manufacture of products. It covers the various stages in the manufacture of a product including: energy consumption, environmental impacts, and the selection of appropriate operations. Also included are the materials and methods that may be used.

On successful completion of this unit the student will be able to identify the fundamental methods and stages in product manufacture within their industry. Students will have the opportunity to investigate some, or a combination of, particular operations including manual and automated systems, fixed-time sequential systems, batch operations requiring inventory transfer and lead time, flow and bulk transfer and chemical and thermal processes in which a change of state occur. Students will also be able to describe how sustainability considerations, for example, energy consumption or environmental impact, are an essential part of the manufacturing process.

Learning Outcomes

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

1. Investigate pre-manufacturing supply chain processes
2. Review processes used to manufacture products
3. Define manufacturing systems by product type
4. Describe the post-manufacturing supply chain process.

Essential Content

LO1 **Investigate pre-manufacturing supply chain processes**

Supply chain relationship and management

Purchasing and supply systems

Quality assurance, control of raw materials, goods inward

Safe handling, storage and distribution of parts and raw materials to the process

Effectiveness of pre-manufacturing supply chain processes in terms of cost, sustainability, Health and Safety, quality and productivity.

LO2 **Review processes used to manufacture products**

Types of manufacturing process

Processing technologies

Automation

Chemical and thermal processes

Separation and extraction methods

Fabrication

Material shaping and removal

Additive processes

Joining and assembly.

Material handling and storage systems

Manual handling

Automated handling

Conveyor systems

Pumping

Storage.

Manufacturing process characteristics

Selection

Capability including surface finish

Tolerances

Volume and variety and effects on manufacturing costs, efficiencies, process changeovers/set up

Health and safety.

Quality systems

Quality control

Product defects and causes

Lean processes

Kanban/just in time (jit).

Sustainability

Selection of materials

By-product and waste disposal

Rework/scrappage

Environmental impacts

Corporate image

Legislation and regulatory requirements

Energy consumed

Carbon footprint.

LO3 **Define manufacturing systems by product type**

Selection of manufacturing process

Sequential fixed-cycle operations

Batch operations with inventory transfer and lead time

Flow and bulk transfer

Chemical and thermal operations involving a change of state.

Manufacturing cycle

impact on upstream and downstream processes

Design and layout of the overall production system

Production volume, automation, manual production

Production strategies, scale of investment, embedded investments

LO4 **Describe the post-manufacturing supply chain process**

Finished product

Supply chain process

Shipping of finished products

Distribution system.

Handling and storage methods

Packaging

Containers

Final quality assurance

Acceptable quality levels

Defect detection

Distribution system.

Management of finished products; quality assurance methods,

End user

client relationship

corporate image.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate pre-manufacturing supply chain processes		**D1** Evaluate how the timely supply and quality of components and raw materials impact upon the manufacturing process
P1 Investigate the supply chain processes used to provide components and raw materials to the manufacturing process **P2** Explain the function of the purchasing, quality assurance and goods inwards departments in relation to the supply of components and raw materials	**M1** Analyse how the acquisition and quality of raw materials and components is controlled	
LO2 Review processes used to manufacture products		**D2** Justify the processes and methods selected to manufacture the given multi-part product in terms of sustainability
P3 Review the manufacturing processes that safely manufacture multi-part products **P4** Review the materials handling and storage systems used in the manufacture of multi-part products	**M2** Analyse the suitability of the manufacturing processes and materials handling and storage methods selected to safely manufacture a given multi-part product	
LO3 Define manufacturing systems by product type		**D3** Evaluate how production strategies for high, medium and low volume production may be influenced by the scale of investment
P5 Explain how the nature of the product determines the selection of a particular manufacturing process **P6** Define how manufacturing processes influence the layout of the overall production system	**M3** Analyse how production volume influences the selection of manufacturing process and layout	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO4 Describe the post-manufacturing supply chain process</td><td rowspan="2">D4 Evaluate how quality assurance methods, storing and shipping of finished products impact on corporate image/reputation.</td></tr>
<tr><td>P7 Investigate the supply chain processes used to provide finished products to customers

P8 Describe the handling and storage of finished goods</td><td>M4 Analyse finished product quality management processes</td></tr>
</table>

Recommended Resources

Textbooks

BLACK, J.T. and KOHSHER, R.A. (2017) *Degarmo's Materials and Processes in Manufacturing.* 12th ed. New Jersey: Wiley.

FELLOWS, P.J. (2017) *Food Processing Technology Principles and Practice*. 4th ed. Cambridge: Woodhead Publishing.

KAUSHISH, J.P. (2010) *Manufacturing Processes*. 2nd ed. New Delhi: PHI Learning.

KAZMER, D. (2009) *Plastics Manufacturing Systems Engineering.* Munich: Hanser Publications.

STRONG, A.B. (2008) *Fundamentals of Composites Manufacturing Materials, Methods and Applications.* 2nd ed. Michigan: Society of Manufacturing Engineers.

Websites

www.engineershandbook.com	Engineer's Handbook Manufacturing Processes (General Reference)
www.thelibraryofmanufacturing.com	The Library of Manufacturing (General Reference)
www.hitachirail-eu.com	SlideShare Garment manufacturing process from fabric to poduct (General Reference)

Links

This unit links to the following related units:

Unit 2: Manufacturing Planning and Scheduling Principles

Unit 6: Material Handling Systems

Unit 22: Introduction to Manufacturing Systems Engineering

Unit 13: Sustainability and the Environment in the Manufacturing Industry

Unit 15: Creating and Managing Projects in Manufacturing Operations

Unit 2: Manufacturing Planning and Scheduling Principles

Unit code	**A/617/3920**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

Planning is an essential skill for all engineers. The manufacturing industry demands an efficient and effective approach to high volume production to ensure costs are minimised and potential problems identified and solved quickly. This unit will develop students' understanding of the methodologies and techniques that are used in process planning and scheduling and will enable them to plan and schedule a manufacturing activity.

Students will develop an understanding of how manufactured products and their associated processes are planned, monitored and controlled and extend their knowledge of, and ability to apply, both manual and computer-assisted methods and procedures.

The unit covers process plans (for example forecasting, network analysis, etc.), capacity assessment and scheduling. This leads into inventory management, with stock control and documentation systems being an important element.

On successful completion of this unit students will be able to explain the techniques used to plan manufacturing and scheduling activities. The skills developed will allow the student to consider alternative approaches and choose the most effective method to achieve efficient production.

Learning Outcomes

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

1. Review methods of process planning and capacity assessment of manufacturing processes
2. Outline techniques of inventory management, stock control, use of documentation control systems
3. Demonstrate methods to classify and code component parts as key elements of group technology and efficient production
4. Plan and schedule a manufacturing activity.

Essential Content

LO1 **Review methods of process planning and capacity assessment of manufacturing processes**

Process planning:

Forecasting

Network analysis

Critical path method (CPM)

Project evaluation and review technique (PERT)

Material requirement planning (MRP II)

Make or buy decisions

Computer-aided planning and estimating

Enterprise resource planning (ERP).

Capacity requirements planning (CRP):

Bill of materials (BOM)

Economic batch size

Availability of labour

Equipment and tooling

Methods of increasing/decreasing capacity and time standards.

LO2 **Outline techniques of inventory management, stock control, use of documentation control systems**

Materials and manufacturing processes:

Better utilisation of raw materials and energy

Integration of design and manufacturing activities

Introduction of new processes and techniques

Unmanned production/intelligent processing

Introduction of new materials

New manufacturing process technology.

Inventory management:

Types of inventory

Dependent and independent demand

Buffer stock

Cost of inventory.

Stock control systems:

Periodic review

Re-order points

Two-bin system

Basic economic order quantities (EOQ)

Kanban/Just In Time (JIT).

Documentation controls:

Flow processes

Work orders

Routine documentation

Job tickets

Finished quantities

Rework and scrap

Stock records.

Shop control:

Release of works orders

Work in progress (WIP)

Quality checks and inspection

Data collection and feedback.

LO3 **Demonstrate methods to classify and code component parts as key elements of group technology and efficient production**

Classifying and coding:

Sequential

Product

Production

Design

Opitz method

Classification of parts into families for efficient mass production.

Grouped facilities:

Layout

Product

Process

Fixed position

Flexibility

Grouping and sequencing of facilities of parts to minimise delays

Material handling.

LO4 **Plan and schedule a manufacturing activity.**

Process plan:

Forecasting to identify timings and throughput

Provision of materials

Equipment and tooling

Methods and processes needed

Labour requirements

Inspection

Workmanship standards and quality checks

Data logging and use of computer-based systems.

Production schedule:

Process planning

Customer requirements

Lead times

Using scheduling techniques

CPM

Gantt charts

OPT

MRP II

Aided by software packages.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Review methods of process planning and capacity assessment of manufacturing processes</td><td rowspan="4">LO1 and LO2
D1 Evaluate the processes necessary to ensure a given product is manufactured efficiently</td></tr>
<tr><td>P1 Explain different process planning techniques
P2 Explain the use of capacity assessment for different types of manufacturing process</td><td>M1 Analyse different process planning techniques and capacity assessment for a given manufactured product</td></tr>
<tr><td colspan="2">LO2 Outline techniques of inventory management, stock control, use of documentation control systems</td></tr>
<tr><td>P3 Outline materials and manufacturing processes for a given manufactured product
P4 Identify the critical elements of inventory management
P5 Explain different shop floor documentation systems</td><td>M2 Show how materials and manufacturing processes support an inventory management system for a given manufactured product and how this would interface with a shop floor documentation system</td></tr>
</table>

Pass	Merit	Distinction
LO3 Demonstrate methods to classify and code component parts as key elements of group technology and efficient production		**LO3 and LO4**
P6 Describe how component parts are classified into families for manufacturing purposes **P7** Illustrate how shop floor layout is designed to maximise production of multi-part products	**M3** Analyse how the classification of facilities of parts determines the layout and process flow of a given multi-part product	**D2** Evaluate the process plan and production schedule for the efficient part delivery, layout, scheduling and manufacture of a given multi-part product
LO4 Plan and schedule a manufacturing activity.		
P8 Produce a process plan for a given multi-part product **P9** Produce a production schedule for a given multi-part product from its process plan	**M4** Analyse the benefits of a process plan and production schedule for a given multi-part product	

Recommended Resources

Textbooks

PROUD, J.F (2013) *Master Scheduling.* 3rd ed. Hobolken, New Jersey: John Wiley and Sons.

SMITH, R. and WILSON, J. (2010) *Planning and Scheduling Made Simple.* 3rd ed. Fort Meyers, Florida: Reliabilityweb.com.

Links

This unit links to the following related units:

Unit 1: Manufacturing Processes

Unit 6: Material Handling Systems

Unit 7: Workplace Study and Ergonomics

Unit 8: Business Improvement Techniques for Engineers

Unit 15: Creating and Managing Projects in Manufacturing Operations

Unit 22: Introduction to Manufacturing Systems Engineering

Unit 29: Quality and Process Improvement

Unit 3: Statistical Process Control

Unit code R/617/3924

Unit level 4

Credit value 15

Introduction

Control charts and measurements are methods used to detect trends and quality variations in the output of processes, allowing early warnings of deviations from specifications. These signals are then used to initiate corrective actions in production planning, process method, modification and maintenance of systems. SPC forms an important part of most process improvement methodologies, such as Total Quality Management and Six Sigma.

This unit introduces the student to the statistical techniques used in process control, variables inspection and attributes inspection. The collection and handling of data and its interpretation using process control charts is covered. These skills will allow the student to assess process capability and recognise types of variability that may occur in different processes.

By the end of this unit, students will be able to apply relevant statistical techniques used in process quality control and to evaluate the outcome of a process against the desired specification.

Learning Outcomes

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

1. Review the quality control function of inspection and measurement
2. Select data to construct process control charts and determine a control program for a specified application
3. Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits
4. Report the variation found within the output of a process.

Essential Content

LO1 **Explain traction and rolling stock systems, subsystems and components and how they interact**

Importance of quality control in all organisations:

Use of basic techniques to meet the objectives of quality control
Evaluation of basic types, variables inspection, precision measurements of physical characteristic, e.g. weight, surface finish etc.
Attribute inspection: Pass/Fail, Go/NoGo, Accept/Reject.

Variability:

All processes are subject to some degree of natural and assignable variability which may change due to process methods used and cumulative effects such as wear and tear on individual components.

Mathematical methods:

Used to quantify variations and characteristics: frequency, mean, standard deviation (SD)

Control limits/allowable tolerances within specified standard deviation values considered.

Accuracy:

Function of the accuracy of the process; relate to the design specification requirement

Errors in tool setting, wear and tear, material variation and skill of operator/programming.

LO2 **Select data to construct process control charts and determine a control program for a specified application**

Sample data:

Physical variables and attributes such as weight, length, diameter

Defects per unit area/length

Data grouping:

Data grouped in tabular form, sample means

Bulk means and SD values calculated using appropriate software

Process and control charts created

Upper and lower control limits decided, based on appropriate standards to meet design specification conditions.

LO3 **Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits**

Modified control charts:

Allowing flexibility to respond to long-term variations, whilst maintaining control within specified tolerances.

Limits:

Distinction between specification limits and control chart limits

Reduction of variability and the effects on precision in terms of SD for a particular component or product

The relative precision index of a process and hence its capability and capacity.

LO4 **Report the variation found within the output of a process.**

Types of variation:

Process used

Common effects

Special effect.

Recording variation:

Charts – linear recording, time versus output, histograms, Pareto diagrams, stem and leaf plots

Computer data acquisition systems and visual display benefits.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Review the quality control function of inspection and measurement</td><td rowspan="2">D1 Evaluate how the monitoring of process outputs can be used to ensure standards and conformance to a given design specification are maintained</td></tr>
<tr><td>P1 Review the importance of inspection and measurement in the quality control of a process

P2 Distinguish the significance between natural and assignable causes of variation</td><td>M1 Analyse data to construct the frequency distribution and calculate the mean, range and standard deviation of a given process</td></tr>
<tr><td colspan="2">LO2 Select data to construct process control charts and determine a control program for a specified application</td><td rowspan="2">D2 Initiate a control program for a specified application</td></tr>
<tr><td>P3 Explain how data can be chosen to create process control charts that will enable decisions to be made effectively

P4 Select data to construct process control charts and present</td><td>M2 Analyse sample data from variable inspection and attributive inspection to determine appropriate control chart limits</td></tr>
</table>

Pass	Merit	Distinction
LO3 Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits		**D3** Evaluate the processes of a system against a given quality requirement
P5 Describe the characteristics that need to be considered when determining the process capability of a given process	**M3** Analyse the purpose of modified control chart limits	
LO4 Report the variation found within the output of a process**.**		**D4** Determine an effective response to any deviation from the acceptable quality thresholds
P6 Demonstrate effective and accurate methods to record variation in output quality of a range of processes	**M4** Analyse variations of a process output and deduce cause and effect on finished artefact or service	

Recommended Resources

Textbooks

AMSDEN, R.T. and D.M. (1998) *SPC Simplified: Practical Steps to Quality*. New York: Productivity Press.

WHEELER, D.J. (2010) *Understanding SPC*. 3rd ed. Knoxville, Tennessee: SPC Press.

Links

This unit links to the following related units:

Unit 7: Workplace Study and Ergonomics

Unit 8: Business Improvement Techniques for Engineers

Unit 11: Lean Techniques for Manufacturing Operations

Unit 23: Engineering Design

Unit 29: Quality and Process Improvement

Unit 4: Manufacturing Operations Mathematics

Unit code	**Y/617/3925**
Unit level	**4**
Credit value	**15**

Introduction

Mathematics is an important discipline in many subjects: it supports decision making and problem solving within many sectors of engineering and business. It is essential that people working in the manufacturing industry, which is wide and varied, apply mathematics in the context of the manufacturing environment, for example to calculate how many parts or products would need to be manufactured to meet a customer's order, to measure and identify any weaknesses in a manufacturing process and to predict possible outcomes.

The mathematics delivered in this unit is directly applicable to the manufacturing sector. The unit will provide the opportunities to develop the necessary mathematical knowledge and understanding to support the broad underlying principles allied to the manufacturing industry.

Students will be introduced to the mathematical methods and techniques required to understand, analyse and solve problems within a manufacturing context. The importance of mathematics in this sector is crucial in ensuring the quality and repeatability of production. The exacting standards demanded require skilled personnel with a full appreciation of not only mathematical knowledge but the practical skills to measure, monitor and control processes within a manufacturing role.

On successful completion of this unit students will be able to apply mathematical methods within a variety of contextualised examples, interpret data from a variety of sources, such as tables, graphs and diagrams, including statistical and computational techniques to solve manufacturing problems. The student will be introduced to software packages such as Excel, Matlab, Autocad and Solidworks.

Learning Outcomes

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

1. Develop arithmetic techniques to accurately measure and calculate component characteristics, production data and qualify standards of output
2. Apply a variety of statistical and probability techniques to interpret information and organise and present data
3. Investigate analytical and computer-based methods to help decision making in solving manufacturing problems
4. Plan and schedule a manufacturing activity.

Essential Content

LO1 **Develop arithmetic techniques to accurately measure and calculate component characteristics, production data and qualify standards of output**

Mathematical concepts:

Introduction to dimensional analysis and indices

Arithmetic and geometric progressions

Trigonometry

Standard units and derived units of measurement

Measurement techniques

Accuracy and inaccuracy

Precision, repeatability and reproducibility

Tolerances.

LO2 **Apply a variety of statistical and probability techniques to interpret information and organise and present data**

Data handling and statistical analysis:

Mean and median values

Standard deviation and variance

Graphical data analysis

Frequency distributions

Standard error of mean

Distribution of manufacturing tolerances.

Probability theory:

Gaussian distribution

Probability density function

Reliability.

LO3 **Investigate analytical and computer-based methods to help decision making in solving manufacturing problems**

Use of computers and data logging techniques to collect and assist in analysis of data, in costing and to apply quality control techniques

Introduction to statistical process control (SPC)

To increase process improvement

Reduction of variability

Use of real-time data

Data plotting.

Compliance with standards

LO4 **Plan and schedule a manufacturing activity**

Forecast timings and completion rate of manufacturing processes

Identify the availability of materials and equipment needed for a given activity

Assess reliability of production techniques

Mean time to failure (MTTF)

Mean time to repair (MTTR)

Prediction of failure rates and effect of downtime on production schedules.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Develop arithmetic techniques to accurately measure and calculate component characteristics, production data and qualify standards of output		**LO1 and LO2** **D1** Evaluate the use of manufacturing and production data to support decision making
P1 Develop arithmetic techniques to accurately measure components' characteristics **P2** Calculate numerical problems using standard and derived units of measurement **P3** Apply data to determine the accuracy and tolerances of manufactured parts	**M1** Apply analytical techniques to solve contextualised problems in manufacturing	
LO2 Apply a variety of statistical and probability techniques to interpret information and organise and present data		
P4 Summarise data by calculating mean and standard deviation of various manufactured products/parts **P5** Calculate likely probabilities using frequency and Gaussian distributions of manufactured products	**M2** Interpret the results of a statistical hypothesis test conducted from a manufacturing scenario	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Investigate analytical and computer-based methods to help decision making in solving manufacturing problems</td><td rowspan="4">LO3 and LO4

D3 Demonstrate a hypothetical manufacturing process (case study) and analyse the expected output against the probability of what may happen in a real manufacturing system</td></tr>
<tr><td>P6 Solve manufacturing problems using mathematical and computer-based methods

P7 Present data accurately in a spreadsheet to identify trends and confirm the outcomes of a manufacturing activity</td><td>M3 Carry out calculations via a computer-based package to confirm the outcomes and support decision making</td></tr>
<tr><td colspan="2">LO4 Plan and schedule a manufacturing activity.</td></tr>
<tr><td>P8 Explain how production forecasts are created and what may affect their accuracy

P9 Illustrate how customer requirements are modelled mathematically to produce a workable production schedule, using a GANTT chart</td><td>M4 Produce a critical path analysis of the production of an engineering product</td></tr>
</table>

Recommended Resources

Textbooks

BURKE, R. (2013) *Project Management, Planning & Control Techniques*. 5th ed. Chichester: John Wiley and Sons.

STROUD, K.A. and BOOTH, D.J. (2013) Engineering maths. 7th ed. Basingstoke: Palgrave Macmillan.

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

Websites

www.elsevier.com	Elsevier
	Journal of Manufacturing Systems (Journal)
www.bluepenjournals.org	Blue Pen Journals Journal of Engineering and Manufacturing Technology (Journal)

Other resources

Centres will need to ensure students are able to have access the following software packages: Excel and MATLAB.

Awareness of other software packages such as Autocad and Solidworks would also be of benefit to the student.

Links

This unit links to the following related units:

Unit 5: Engineering maths

Unit 24: Engineering Science

Unit 5: 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

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Identify the relevance of mathematical methods to a variety of conceptualised engineering examples</td><td rowspan="4">LO1 & LO2

D1 Present data in a method that can be understood by a non-technical audience</td></tr>
<tr><td>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</td><td>M1 Use dimensional analysis to derive equations</td></tr>
<tr><td colspan="2">LO2 Investigate applications of statistical techniques to interpret, organise and present data</td></tr>
<tr><td>P4 Summarise data by calculating mean and standard deviation

P5 Calculate probabilities within both binomially distributed and normally distributed random variables</td><td>M2 Interpret the results of a statistical hypothesis test conducted from a given scenario</td></tr>
</table>

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering application</td><td rowspan="2">D2 Model the combination of sine waves graphically and analyse the variation in results between graphical and analytical methods</td></tr>
<tr><td>P6 Solve engineering problems relating to sinusoidal functions

P7 Represent engineering quantities in vector form, and use appropriate methodology to determine engineering parameters</td><td>M3 Use compound angle identities to combine individual sine waves into a single wave</td></tr>
<tr><td colspan="2">LO4 Examine how differential and integral calculus can be used to solve engineering problems</td><td rowspan="2">D3 Analyse maxima and minima of increasing and decreasing functions using higher order derivatives</td></tr>
<tr><td>P8 Determine rates of change for algebraic, logarithmic and trigonometric functions

P9 Use integral calculus to solve practical problems relating to engineering</td><td>M4 Formulate predictions of exponential growth and decay models using integration methods</td></tr>
</table>

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 4: Manufacturing Operations Mathematics
Unit 24: Engineering Science

Unit 6: Material Handling Systems

Unit code D/617/3926

Unit level 4

Credit value 15

Introduction

Material handling is the movement of raw materials and partly or fully finished components/products within a manufacturing operation or between the operation and a method of transportation.

It employs a wide range of manual, semi-automated and automated equipment and includes consideration of the planning of the handling processes and the protection, storage, and control of the materials or components throughout their time in the manufacturing facility.

The unit introduces the student to the aims and strategies used in the logistics of material handling and the stages involved in the process. The criteria for the selection of material handling equipment will be explored as will the comparison of available systems using appropriate analysis tools. The planning, tracking and identification methods used, together with an analysis of their effectiveness, will also be covered.

On successful completion of this unit the student will be able to explain the principles of material handling and be able to plan and monitor operations and equipment and to analyse the effectiveness of the process.

Learning Outcomes

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

1. Describe the aims, strategies and logistics models used for material handling systems
2. Explain the operation of a range of material handling systems
3. Review the methods of control used in material handling systems
4. Undertake planning the layout of a material handling system.

Essential Content

LO1 **Describe the aims, strategies and logistics models used for material handling systems**

Aims of material handling systems: flow of materials; movement of work in progress, minimising cost of holding stock and maintaining high quality

Stages of engineering material handling: selection and loading; moving and unloading; placement and positioning; materials including raw materials, components, sub-assemblies, parts, tools and consumables

Strategies used: eliminate handling or movement; combine processing and movement; use automation or mechanical handling; use correct equipment in an appropriate manner; use unit loads, pallets and or containers to avoid mixing materials; practise economy of movement; recognise central authority and control of operation.

LO2 **Explain the operation of a range of material handling systems**

Criteria for the selection of a material handling system: industry-specific constraints, e.g. freshness, danger of contamination; location of material centres; material type and appropriate handling conditions; capital and resources available; future needs – expansion or contraction of operation; total cost of the handling system; compatibility with existing equipment and systems technologies

Material handling systems: centrally coordinated and controlled systems; systems controlled by individual departments; automated and semi-automated systems

Cost benefit analysis: benefits, e.g. reduced accidents and losses, increased capacity, speed, space, flexibility; 'double handling' bottlenecks and accidents; cost of designing, installing, staffing and maintaining.

LO3 **Review the methods of control used in material handling systems**

Control of material flow: computer-controlled networks; programmable logic controllers (PLCs); dedicated software; departmental control panels; automated storage and retrieval systems (ASRs); robots; radio-controlled vehicles; closed-circuit TV; advanced guided vehicles (AGVs) with on board computers.

Tracking and identification: voice recognition; coding systems; job tickets; radio-frequency identification (RFID); recording devices such as bar code readers, optical character recognition (OCR), numbers input manually. Identification devices such as optical sensors, proximity sensors.

Controlled material handling system: using material flow processes, dedicated or non-specialist material handling programmes to represent the control of a material handling system; detailed critical analysis of all decisions made; details of all critical control points; critical path network diagrams; other graphical communication techniques.

LO4 **Undertake planning the layout of a material handling system.**

Types of material handling equipment: cranes, lifts, vehicles, conveyors, pneumatic and hydraulic equipment, towing equipment, chutes, palletising systems, and robots

Application of a range of equipment, e.g.: overhead, vertical, horizontal, horizontal fixed-route, horizontal non-fixed route equipment; speed of the equipment

Factors influencing selection of material handling equipment, e.g.: features, size, weight, nature and volume of the materials; rate of movement required; route of movement; storage before and after movement; safety/hazards and concurrent processing

Planning the layout:

Features of modern material handling systems

Detailed analysis of material movement needs, work-study and layout and planning techniques

Handling conditions required by the materials; requirements and constraints of the material handling system

Critical path analysis techniques

Gantt charts to determine key processes, procedures, sequence of events, equipment and time requirements

Technical and graphical techniques to illustrate final layout.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Describe the aims, strategies and logistics models used for material handling systems</td><td rowspan="2">D1 Evaluate the effectiveness of the different strategies that might be employed to create a material handling system for a given application</td></tr>
<tr><td>P1 Review the aims of a typical manufacturing material handling system
P2 Describe the stages of engineering material handling</td><td>M1 Analyse the strategies employed to achieve each stage of the material handling process</td></tr>
<tr><td colspan="2">LO2 Explain the operation of a range of material handling systems</td><td rowspan="2">D2 Carry out a cost−benefit analysis by comparing two modern material handling systems</td></tr>
<tr><td>P3 Detail the criteria used for the selection of a material handling system
P4 Explain the main causes of bottlenecks in material handling systems</td><td>M2 Analyse the advantages and disadvantages of a centrally coordinated and controlled operation, compared with one controlled by individual departments</td></tr>
</table>

Pass	Merit	Distinction
LO3 Review the methods of control used in material handling systems		**D3** Evaluate a controlled material handling system
P5 Review the methods used for the control of material flow in a material handling system **P6** Explain the need for tracking and identification as part of a material handling system	**M3** Analyse the effectiveness of a given process for the control of material flow	
LO4 Undertake planning the layout of a material handling system.		**D4** Evaluate the movements, conditions, requirements and constraints of the proposed material handling system
P7 Review the most important features of modern material handling systems **P8** Assess the main Health and Safety concerns in a given material handling system	**M4** Construct a layout of the proposed system using appropriate graphical techniques	

Recommended Resources

Websites

www.warehousenews.co.uk	Warehouse News Warehouse and Logistics (General Reference)

Links

This unit links to the following related units:

Unit 12: Monitoring and Fault Diagnosis of Engineering Systems

Unit 17: Industrial Robots

Unit 18: Programmable Logic Controllers (PLCs)

Unit 19: Engineering Plant Operation and Maintenance

Unit 20: Mechatronic Systems in Manufacturing

Unit 30: Maintenance Engineering

Unit 7: Workplace Study and Ergonomics

Unit code	**H/617/3927**
Unit level	**4**
Credit value	**15**

Introduction

The aim of this unit is to develop students' ability to identify and carry out productivity measurement and improvement, ergonomic and plant layout design and work measurement and method study. Understanding the workplace is an important part of any manufacturing operation. Being able to review the processes involved, identify the influencing factors and then review and improve these allows future manufacturing operation to develop and maximise productivity, improve quality and use resources in the most efficient way.

Students will apply several lean manufacturing techniques commonly used to identify and eliminate waste within manufacturing and production environments. Within the unit students will look at real or simulated manufacturing environments and have the opportunity to apply and see skills and techniques at work.

On successful completion of this unit students will be able to analyse manufacturing situations, identify areas for improvement and apply techniques to demonstrate how changes made would improve the productivity of the process, and/or the layout or physical ergonomics of the workplace, and present this information in a suitable format.

Learning Outcomes

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

1. Investigate productivity measurement techniques and the effect of a range of improvement methods
2. Review the features of work measurement and method study techniques
3. Assess the ergonomic and layout planning features of workstation and manufacturing operations design
4. Apply industrial engineering techniques to a given engineering/ manufacturing situation.

Essential Content

LO1 **Investigate productivity measurement techniques and the effect of a range of improvement methods**

Productivity measurement:

Methods of measuring physical factors – labour, materials and equipment; single factor and integrated productivity measurement, critical analysis techniques including cost−benefit analysis and force field analysis

Evaluation may include graphical representations, statistical representations, fitness for purpose considerations and recognition of short-term and long-term effects – e.g. quality, cost, delivery (QCD) metrics; value stream mapping (VSM); process mapping

Productivity improvement:

Reduction in unit cost of manufacture in terms of labour, product, materials, production level or machine automation

Uses of new technology

Efficient manual operation – taking account of work-study; job design; layout and ergonomic design; total quality management (TQM) methods

Reduction in waste of resources (e.g. energy, staff time, materials) – reduction/elimination of the 'eight wastes'; standardised operations and their relevant forms; takt time analysis and production smoothing; change-over analysis, single-minute exchange of dies (SMED)

LO2 **Review the features of work measurement and method study techniques**

Work measurement:

Direct work measurement – time study and activity sampling

Indirect work measurement – synthetic timing

Predetermined motion time systems (PMTS) – methods time measurement (MTM)

Computer-based programs

Primary standard data

Analytical estimating.

Method study:

Job selection

Recording methods and procedures

Method description

Development of improved method

Definition of new method and installation and maintenance

Work measurement and study

Chart format

Simple comparisons

Critical analysis

Ranking techniques

Technique application description

Fitness for purpose.

LO3 **Assess the ergonomic and layout planning features of workstation and manufacturing operations design**

Ergonomic features:

Features of design including worker machine controls

Environmental factors and anthropometrical data used in the design of workstations

Awareness of special features for VDU operators

Role of Health and Safety.

Layout planning features:

Features of design including types of layout

Operation sequence analysis

Layout planning procedures and methods.

Layout design:

Workstation design features such as characteristics of the operator

Interaction between workspace and the operator (e.g. posture, reach, desk/machine size, adjacent machinery, interaction between the environment and the operator)

Assessment techniques:

Develop criteria for good layout of workstation and manufacturing operations

Consider how multiple factors influence the final layout (e.g. flexibility, coordination, volume, visibility, accessibility, distance, handling, discomfort, safety, security, material flow, part identification, *poka yoke* and *jidoka* techniques)

LO4 **Apply industrial engineering techniques to a given engineering/manufacturing situation**

Engineering/manufacturing situation:

Collect information and data on current company aims (e.g. current productivity, measurement, processes, process flow, scheduling, materials, equipment, labour, layout, ergonomic features of labour force and equipment operation)

Present evidence in a relevant form (e.g. graphs, statistics, manuals, diagrams, recorded interviews, recorded observations, computer programs)

Engineering techniques:

Selection and application of techniques (e.g. productivity measurement, productivity improvement, method study, work measurement, ergonomic design, layout planning)

Formulate a plan of action

Appraise the feasibility of the techniques with reference to the engineering/manufacturing situation

Make simple comparisons and use decision-making techniques (e.g. consider fitness for purpose

Long-term and short-term effects on the engineering/manufacturing situation)

Record and justify any changes to current engineering/manufacturing situation

Present findings using relevant methods (e.g. use of graphs, statistics, flow diagrams, layouts, computer programs, graphical techniques, video, file, written reports and technical discussion)

Use appropriate lean manufacturing techniques (e.g. quality, cost, delivery (QCD) metrics, value stream mapping (VSM), process mapping, takt time analysis, production smoothing, pull systems, single-minute exchange of dies (SMED), visual management techniques).

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Investigate productivity measurement techniques and the effect of a range of improvement methods</td><td rowspan="2">D1 Evaluate the impact and use of productivity measurement and improvement methods</td></tr>
<tr><td>P1 Describe techniques of productivity measurement

P2 Describe methods of productivity improvement</td><td>M1 Analyse the usefulness of the range of productivity measurement techniques and productivity improvement methods

M2 Compare the use of productivity measurement techniques and productivity improvement methods and how these are linked</td></tr>
<tr><td colspan="2">LO2 Review the features of work measurement and method study techniques</td><td rowspan="2">D2 Evaluate the use of data within work studies and the impact of using the correct formats for presenting information</td></tr>
<tr><td>P3 Explain how work study comprises work measurement and method study techniques

P4 Describe situations for different uses of work measurement and method study techniques</td><td>M3 Analyse a range of work measurement and work study techniques used for a given situation</td></tr>
</table>

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO3 Assess the ergonomic and layout planning features of workstation and manufacturing operations design</td><td rowspan="4">LO3 and LO4
D3 Design a hypothetical manufacturing layout showing how progression and development has been undertaken to arrive at a final proposal</td></tr>
<tr><td>P5 Describe ergonomic and layout planning features of workstation and manufacturing operations design</td><td>M4 Illustrate how features can be used to support operators and to develop criteria for good layout design</td></tr>
<tr><td colspan="2">LO4 Apply industrial engineering techniques to a given engineering/manufacturing situation</td></tr>
<tr><td>P6 Outline how industrial engineering techniques are selected to analyse a given engineering/ manufacturing situation
P7 Present relevant information/data from a given engineering/ manufacturing situation</td><td>M5 Apply industrial engineering techniques to a given engineering/ manufacturing situation and summarise the impact of the improvements</td></tr>
</table>

Recommended Resources

Textbooks

BURKE, R. (2013) *Project Management, Planning & Control Techniques*. 5th ed. Chichester: John Wiley & Sons.

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

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

Other resources

Many of the techniques involved in industrial engineering use specialist software that may prove expensive. In such cases, Centres will need to ensure that students can view an industrial demonstration of such software at the least.

Links

This unit links to the following related units:

Unit 1: Manufacturing Planning and Scheduling Principles

Unit 2: Manufacturing Process

Unit 14: Manufacturing Operations Mathematics

Unit 15: Industry 4.0

Unit 20: Introduction to Quality and Business Improvement Techniques

Unit 8: Business Improvement Techniques for Engineers

Unit code K/617/3928

Unit level 4

Credit value 15

Introduction

The quality of the output from any business is the key to its success and profitability.

To achieve the highest possible quality at the minimum cost of materials, processes and time, most businesses employ some form of Quality Assurance or business improvement process. These systems are usually company-wide philosophies and practices designed to bring about improvements to the business at all levels.

This unit introduces students to the importance of quality improvement and assurance processes and the principles that underpin them, both to the business and to its customers. The most important continuous improvement processes will be introduced and their applications detailed. In particular, the Six-Sigma methodology will be studied together with an introduction to the application of failure mode and effect analysis techniques and measurement systems analysis. Practical experience of the application of the Six-Sigma system will be undertaken.

On successful completion of this unit the student will be able to explain the development, importance and principles of quality improvement within a business structure, including providing an outline of the most important systems and cost-effective quality practices. They will be able to describe the Six-Sigma methodology in detail and explain the role played by failure mode and effect analysis. The use of worksheets for mistake/error proofing activities will also be considered.

Learning Outcomes

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

1. Explain the importance of quality improvement processes to a business
2. Compare the most commonly used continuous business improvement principles and techniques
3. Examine the origins and key factors of Six-Sigma methodology
4. Apply potential failure modes and effects analysis and create worksheets of mistake/error proofing activities.

Essential Content

LO1 **Explain the importance of quality improvement processes to a business**

Quality:

The importance of quality to companies and customers

How quality underpins a company’s ability to improve efficiency, competitiveness and profitability

The role of standards in improving quality

National, European and international standards.

Quality improvement processes:

The need for logical and progressive processes to examine, check and improve quality

Quality strategies

Local and company-wide quality improvement processes

The success of whole-company quality philosophies worldwide

Attitudes and approaches to the implementation of company-wide (total quality commitment) quality improvement processes

Supply chain considerations.

LO2 **Compare the most commonly used continuous business improvement principles and techniques**

Continuous improvement processes:

Statistical process control (SPC)

Optimised production technology (OPT)

Total productive maintenance (TPM)

Total quality management (TQM)

Six-Sigma; Lean; Six-Sigma Lean.

Continuous Improvement terms and techniques:

Organisational policy and procedures

Quality circles

Production of key performance indicators

Kaizen, Hansel (self-reflection)

Charts and diagrams:

Cause-and-effect diagrams

Check sheets

Control charts

Histograms

Pareto charts

Scatter diagrams

Stratification.

LO3 **Examine the origins and key factors of Six-Sigma methodology**

Origins of Six Sigma:

Origination and development at Motorola, USA in 1980s, from statistical modelling of manufacturing processes.

Roles of Mikel Harry, Bob Galvin and Bill Smith at Motorola.

Development at General Electric and Honeywell.

Six Sigma as a way of doing business

Six Sigma methodology:

Six Sigma as a disciplined, data-driven way of eliminating defects in any process or part of that process

Relationship between mean value and nearest specification limit (six standard deviations)

Key principles: customer-focused; the value stream (how work is done) - manage, improve and smooth work process flow, remove processes that add no value (eliminate waste), manage process by fact (measurement) to reduce variation, involve and train staff at all levels, undertake improvements in a systematic way.

LO4 **Apply potential failure modes and effects analysis and create worksheets of mistake/error proofing activities**

Failure mode and effect analysis (FEMA):

Systematic study of actual or predicted component failure(s) in a design, manufacturing or assembly process and the consequences of such failures (types of failure include component failure, human error in a process)

When to use FEMA: during design or redesign, change of use of component, when modifying manufacturing or assembly process, when analysing in-service failures, during scheduled checking.

Failure/mistakes/error mode proofing worksheets:

Worksheets to record component function, potential failure mode, potential effects of failure, containment plan, potential causes of failure, existing process controls to prevent failure, recommended action, costs and timescales

Use of worksheets to improve quality.

Lessons learnt:

What went well and how to recreate success

Avoiding repetition of past mistakes

Performance improvement on future projects

Commercial impact.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explain the importance of quality improvement processes to a business</td><td rowspan="2">D1 Evaluate the effectiveness of the introduction/use of a company-wide quality programme</td></tr>
<tr><td>P1 Illustrate the importance of quality to a manufacturing organisation
P2 Explore the role of standards in quality improvement</td><td>M1 Analyse how quality improvement can be implemented in a manufacturing setting</td></tr>
<tr><td colspan="2">LO2 Compare the most commonly used continuous business improvement principles and techniques</td><td rowspan="2">D2 Evaluate how data is used to drive continuous improvement processes</td></tr>
<tr><td>P3 Identify the most commonly used continuous business improvement principles and techniques
P4 Identify the differences between operationally specific quality processes and company-wide processes</td><td>M2 Assess the way in which self-reflection is at the heart of any continuous improvement process</td></tr>
</table>

Pass	Merit	Distinction
LO3 Examine the origins and key factors of Six-Sigma methodology		**D3** Evaluate how Six-Sigma can be employed to improve a given manufacturing process
P5 Explain how Six Sigma was developed from earlier statistical modelling techniques **P6** Define the most important elements of the Six-Sigma methodology	**M3** Analyse how standard deviation plays a major part in the Six-Sigma methodology	
LO4 Apply potential failure modes and effects analysis and create worksheets of mistake/error proofing activities.		**D4** Evaluate the information provided by completed failure mode worksheet and suggest appropriate remedial action
P7 Describe the types of failure that can be analysed using failure mode and effect analysis (FEMA) **P8** Review the conditions when the use of failure mode and effect analysis (FEMA) is appropriate in a manufacturing process	**M4** Produce a failure mode worksheet for use in a failure analysis evaluation	

Recommended Resources

Textbooks

OAKLAND, J.S. (2013) *Total Quality Management: Text with Cases*. 3rd ed. Oxford: Butterworth-Heinemann.

PYZDEK, T. and KELLER, P. (2018) *The Six Sigma Handbook*. 5th ed. New York: McGraw-Hill.

Websites

www.asq.org	American Society for Quality (General reference)

Links

This unit links to the following related units:

Unit 7: Workplace Study and Ergonomics

Unit 10: Industry 4.0

Unit 11: Lean Techniques for Manufacturing Operations

Unit 29: Quality and Process Improvement

Unit 9: Dimensional Control of Complex Assemblies

Unit code M/617/3929

Unit level 4

Credit value 15

Introduction

Dimensional control is a key part of the Quality Assurance process that can be applied to any complex assembly. Proper management of dimensional control ensures a high-quality product, which can be manufactured and reliably assembled with the minimum of waste.

The aim of this unit is to identify the range of dimensional control methods and measuring equipment that may be utilised during the manufacture of a complex assembly, including the concepts of repeatability and reproducibility for both measurement and production outcomes and equipment. It will equip the student to show how tolerance changes affect final product conformity and statistical assumptions.

On successful completion of this unit the student will be able to identify the differences between dimensional control methods, dimensional measurement methods and the calibration processes. It has been designed to develop the student’s awareness of the principles and applications of dimensional control methods in complex assembly processes to assure product quality.

Learning Outcomes

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

1. Outline the principles and applications of coordinate systems, alignments, locating a point and control
2. Describe the function and purpose of measurement systems encompassing a range of methods including physical and optical
3. Review the principles of tolerance chain analysis in relation to alignment, capability and tolerances throughout the product build cycle
4. Explain the concepts of repeatability and reproducibility for both measurement and production outcomes and equipment.

Essential Content

LO1 **Outline the principles and applications of coordinate systems, alignments, locating a point and control**

Principles and applications:

X, Y, Z coordinate systems

Interpreting engineering drawings and CAD integration.

Alignments:

Car alignment and local alignments, with reference to key datums

Geometric dimensioning and tolerancing (GDT)

Identifying feature controls.

Adherence to quality standards:

ISO/TC 213 – dimensional and geometrical product specifications and verification

ISO 5459:2011 – geometrical product specifications (GPS)

Geometrical tolerancing

Datums and datum systems

Impact of non-conformance.

LO2 **Describe the function and purpose of measurement systems encompassing a range of methods including physical and optical**

Areas where process and production data can be collected:

Non-contact sensors; laser scanners; fringe projection system.

Data collection and analysis:

Real-time machine tool data collection; interpretation of measurement data

Principles, benefits and limitations of CNC-controlled coordinate measuring machines and contact scanning probes:

Importance of traceability of measurement to national standards

Traceability met through calibration and verification

Test equipment

Jig calibration

Benefits of utilising measuring equipment on the production floor (inline measurement, measurement assisted assembly)

LO3 **Review the principles of tolerance chain analysis in relation to alignment, capability and tolerances throughout the product build cycle**

Benefits of tolerance management:

Introduction to tolerance management

Functional measurement concept process

Tolerance management throughout the product build process

Essential features of tolerance chain analysis:

How tolerance chain analysis works

How tolerance chain analysis results are delivered

Use of tolerance management statistics to confirm conformance to specification

LO4 **Explain the concepts of repeatability and reproducibility for both measurement and production outcomes and equipment**

Concepts of repeatability and reproducibility:

Gauge repeatability and reproducibility (Gauge RR)

Measurement and production outcomes and equipment:

Precision of a measurement system; precision/tolerance ratio

Measurement uncertainty and uncertainty budget

Relationship between quality and measurement uncertainty

Approval of service.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Outline the principles and applications of coordinate systems, alignments, locating a point and control		**D1** Evaluate the function of feature control frame applications with datum references
P1 Outline the underpinning principles of XYZ coordinate systems **P2** Identify the most frequently used geometric characteristic symbols	**M1** Analyse how the relevant quality standards affect the operation of dimensional control systems	
LO2 Describe the function and purpose of measurement systems encompassing a range of methods including physical and optical		**D2** Evaluate the principles, benefits and limitations of Computer Numerically Controlled (CNC) Coordinate Measuring Machines and contact scanning probes
P3 Identify the areas where process and production data can be collected **P4** Outline how the collection and analysis of real-time data collection takes place	**M2** Explain why traceability to national standards is important	
LO3 Review the principles of tolerance chain analysis in relation to alignment, capability and tolerances throughout the product build cycle		**D3** Evaluate how the main features of the tolerance chain analysis process contribute to improved quality in the build process
P5 Outline the essential features of a tolerance management system	**M3** Analyse the benefits of tolerance management throughout the build process	
LO4 Explain the concepts of repeatability and reproducibility for both measurement and production outcomes and equipment.		**D4** Evaluate the benefits of linking coordinate measuring machines (CMMs) to statistical process control software
P6 Describe the concepts of repeatability and reproducibility **P7** Outline how precision and tolerance are linked in the build process	**M4** Illustrate how measurement uncertainty and quality are linked in the build process	

Recommended Resources

Textbooks

BALAGUER, P. (2013) *Application of Dimensional Analysis in Systems Modeling and Control Design*. London: Institute of Engineering Technology (IET).

LARSON, C. (2014) *Dimensional Control Fundamentals: Automotive Body-in-White and Interior Trim. Dimensional Management Book 2*. New Jersey: Right Tech.

TIMINGS, R. (ed). (1988) Chapter 4: Measurement and dimensional control, *Basic Engineering Control*. New York: Butterworth Heinemann.

Links

This unit links to the following related units:

Unit 28: Instrumentation and Control Systems

Unit 29: Quality and Process Improvement

Unit 10: Industry 4.0

Unit code F/617/3949

Unit level 4

Credit value 15

Introduction

Industry 4.0 is the term that has been adopted to describe the 'fourth' industrial revolution currently underway, at present, in the manufacturing and commercial sectors of our society. It is a revolution based on the integration of cyber-physical systems 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.

The aim of this unit is to provide a principle understanding of why and how smart factories are changing the face of manufacturing. Students are first introduced to the factors and consequences behind industrial revolutions and the definition of smart factories followed by the wide range of technologies that make smart factories work. Students will then be able to reflect on successful case studies of transitioning to Industry 4.0 followed by considering possible future directions with respect to Industry 5.0 – personalisation.

On successful completion of this unit students will be able to investigate and evaluate industrial revolutions along with the characteristics and technologies of smart factories. As potential managers, students will also be able to assess the implications of moving to Industry 4.0 and anticipate the likely features of a fifth industrial revolution.

Learning Outcomes

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

1. Investigate the factors leading to the fourth industrial revolution and the characteristics of a smart factory
2. Review the range of cyber-physical technologies shaping Industry 4.0 and the benefits to suppliers, producers and customers
3. Examine the factors manufacturers need to consider when transitioning from Industry 3.0 to 4.0
4. Explore futuristic trends in manufacturing and the factors shaping Industry 5.0.

Essential Content

LO1 **Investigate the factors leading to the fourth industrial revolution and the characteristics of a smart factory**

Aspects of industrial revolutions:

Energy

Transportation

social mobility

socio-economics

business

emerging technologies

science

materials

communications

geography.

Areas of impact of industrial revolutions:

Workforce

Skills

Efficiency

Change management.

Characteristics of a smart factory:

Connectivity

Flexibility

Scalability

Agility

Autonomy

Efficiency.

Techniques relevant to smart factories:

Data analytics

Forecasting

Data visualisation

Quality control.

Practical support:

Physical and decision-making support.

LO2 **Review the range of cyber-physical technologies shaping Industry 4.0 and the benefits to suppliers, producers and customers**

Cyber-physical production systems (CPPS):

Definition

Characteristics

Architecture

Benefits and applications

Support and training for the workforce.

Internet of things (IoT) features:

Artificial intelligence (AI)

Connectivity

Sensors

Platforms.

Wireless communication protocols:

NFC

RFID

Bluetooth

Low-Energy Wireless

Zigbee

Z-Wave

Thread

LTE-A

WiFi-Direct

LPWAN

Light Fidelity (Lifi).

Data analytics:

Definition

Big Data; types – streaming, spatial, time series, prescriptive, predictive and decisive analytics.

Cloud computing:

Types – Saas, IaaS, Paas

Benefits for IoT; developments – edge computing.

LO3 **Examine the factors manufacturers need to consider when transitioning from Industry 3.0 to 4.0**

Data management:

Collection

Storage

Visualisation.

Cyber-security:

Integrated security

Encryption

Risk analysis

Authorisation.

Process and governance:

Managing self-optimisation

Supply chains

Customers.

Workforce:

New roles

Skills gap

Training

Change management

Restructuring of organisations

Employment demographics

Relationship between technological unemployment and education.

Functional safety standards

IEC 61508 (Electrical, Electronic and Programmable Electronic Devices)

IEC 61511 (Industrial Processes)

IEC 62061 (Machinery)

ISO 10218 (Industrial Robots)

IEC 61784, EN 50159, IEC 62280 (Networking)

IEC 62443 (Security).

LO4 **Explore futuristic trends in manufacturing and the factors shaping Industry 5.0**

Stakeholders:

Manufacturing organisations

Governments

Regulator

Professional associations

Suppliers

Market analysts

Educational institutions

Non-profit organisations.

Emerging technologies:

Cognitive computing

3D printing

Augmented reality

Block chain

AI

Voice-controlled user interfaces

Virtual reality.

Standardisation of technologies:

Application interfaces

Integration points

Automation technologies.

Supplier, manufacturer and customer integration: customer as a user contributor.

Customisation:

Harmonisation of human intelligence and cognitive computing

Collaborative robots

Mass personalisation for customers

Role of the human designer.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate the factors leading to the fourth industrial revolution and the characteristics of a smart factory		**D1.** Evaluate the socio-economic impact of industrial revolutions and the global response to Industry 4.0
P1 Investigate the key milestones of industrial revolutions leading to the smart factory **P2** Describe the characteristics of an Industry 4.0 compliant smart factory	**M1** Analyse the key historical factors that have contributed to industrial revolutions leading to Industry 4.0 compliant smart factories	
LO2 Review the range of cyber-physical technologies shaping Industry 4.0 and the benefits to suppliers, producers and customers		**D2.** Evaluate the design and implementation of a cyber-physical systems architecture for Industry 4.0 based manufacturing systems
P3 Examine the relationship between cyber-physical production systems (CPPS) and the Internet of Things (IoT) **P4** Review a range of wireless communication protocols available for the smart factory	**M2** Analyse the principles and benefits of cloud computing and its role with suppliers, manufacturers and customers within Industry 4.0 **M3** Investigate the challenges and solutions regarding data analytics in smart factories	
LO3 Examine the factors manufacturers need to consider when transitioning from Industry 3.0 to 4.0		**D3** Evaluate the organisational impact and change management methods used when transitioning from Industry 3.0 to 4.0
P5 Examine the considerations and challenges manufacturers need to consider when implementing data collection and data management for a smart factory **P6** Explore the transition from Industry 3.0 to 4.0, within a manufacturing sector	**M4** Explore the functional safety considerations when transitioning to a fully automated smart factory	

Pass	Merit	Distinction
LO4 Explore futuristic trends in manufacturing and the factors shaping Industry 5.0.		**D4** Evaluate the future of manufacturing in Industry 5.0 and beyond
P7 Explore the key factors and stakeholders that are causing a transition from Industry 4.0 to 5.0	**M5** Analyse the skills and roles of the modern manufacturing workforce in Industry 5.0	

Recommended Resources

Textbooks

BARKAI, J. (2016) *The Outcome Economy: How the Industrial Internet of Things is Transforming Everyday Business*. Scotts Valley: CreateSpace Independent Publishing Platform.

GILCHRIST, A. (2016) *Industry 4.0: The Industrial Internet of Things*. New York: Apress.

WINDPASSINGER, N. (2017) *Digitize or Die: Transform your Organisation, Embrace the Digital Evolution, Rise above the Competition*. New York: IoT Hub.

YANEZ, F. (2017) *The Goal is Industry 4.0: Technologies and Trends of the Fourth Industrial Revolution*. Independent Publisher.

YANEZ, F. (2017) *The 20 Key Technologies of Industry 4.0 and Smart Factories: The Road to the Digital Factory of the Future*. Independent Publisher.

Websites

www.infineon.com	Infineon Discoveries, Cloud Computing, Safety and Security with Robots, Industry 4.0, Big Data (General Reference)
www.analog.com	Analog Devices Functional Safety and Industry 4.0 (Article)
www.eurogeography.eu	Eurogeo Depots (General Reference)
www.supplychaingamechanger.com	Supply Chain Game Changer The Industrial Revolution – From Industry 1.0 to Industry 5.0! (Article)
www.advantech.com	AdvanTech Building a Wireless Remote Monitoring and Management System for China’s Leading Electrical Appliance Manufacturer (Case study)
www.plattform-i40.de	Plattform Industrie 4.0 Network Based Communication for Industry 4.0 (Article)
kingstar.com	KingStar Industry 4.0: Key Design Principles (Article)

Unit 11: Lean Techniques for Manufacturing Operations

Unit code	**H/617/3930**
Unit level	**4**
Credit value	**15**

Introduction

Lean manufacturing is a systematic approach to minimising waste in manufacturing operations. The 'lean' approach originated in the car industry and was developed by Toyota in Japan. Lean is now used extensively worldwide, in all types and size of organisation, to improve efficiency and competitiveness.

The aim of this unit is to introduce students to the basic principles and applications of lean manufacturing, so that they can become effective and committed practitioners of lean in whichever sector they work. To do this, the unit will explore the tools and techniques that are applied by organisations practising lean. The students will consider both the benefits and the challenges of using lean, so that they will develop sufficient knowledge about the most important process tools, techniques and applications to be able to operate and use them.

The topics included in this unit are: scoping and defining lean manufacturing; the benefits and challenges of adopting lean; the Toyota Production System (TPS), and other systems; common tools and techniques associated with lean manufacturing and process improvement; and the most appropriate improvement tool(s) to tackle a problem.

On successful completion of this unit, students will be able to explain the origins and common principles of lean manufacturing and utilise a range of the process improvement tools used within lean manufacturing, demonstrating communication skills that will enable them to participate effectively in the process of continuous improvement in the workplace.

Learning Outcomes

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

1. Describe the common principles of lean manufacturing and how the implementation of a lean production system contributes to workplace efficiency
2. Explore the most widely used approaches to lean manufacturing
3. Review a range of the process improvement tools used within lean manufacturing
4. Communicate the challenges and benefit of lean techniques in the workplace.

Essential Content

LO1 **Describe the common principles of lean manufacturing and how the implementation of a lean production system contributes to workplace efficiency**

Describing and defining lean manufacturing:

Manufacturing processes in the immediate post-Second World War period

Origins of lean manufacturing: the need for improved manufacturing processes to improve output, quality and reliability, and reduce costs.

Common principles of lean manufacturing philosophy:

Importance of lean manufacturing to the company, employee, customer

Identification/elimination of material and process wastes that add no value to the final output

Audit of processes, material selection, form, supply, storage, transportation of materials and finished products, plant layout and human factors.

Benefits and challenges of adopting lean:

Reasons an organisation might consider adopting a lean approach to their operations: failing sales and profitability, poor competitiveness, quality and reliability issues, disengaged workforce

Productivity, quality, customer satisfaction, delivery performance in a lean context

The benefits of a lean organisation to the customer, the company and the employees

Challenges and costs of lean implementation: change management, managing expectation, empowerment, motivation, investment and supply chain involvement.

LO2 **Explore the most widely used approaches to lean manufacturing**

Toyota Production System (TPS):

Motivation behind the TPS; the importance of manufacturing to post-Second World War Japan, making Japanese manufacturing more competitive.

Fundamental elements of the TPS; complete elimination of waste of all kinds; Jidoka – 'automation with a human touch'; highlighting and visualisation of problems, preventing defective or sub-standard components being produced.

Just-in-time.

Other quality systems:

Total quality management (TQM), Six Sigma, production systems publicised by other global manufacturers

Adoption of lean manufacturing principles outside manufacturing, e.g. banking, service sector.

LO3 **Review a range of the process improvement tools used within lean manufacturing**

Common tools associated with lean manufacturing and process improvement:

Seven Wastes, continuous flow, Kanban (pull system), just-in-time (JIT), lean simulation activities, value stream mapping, poka-yoke, 5 Whys (root cause analysis), total preventative maintenance (TPM)

Plan-do-check-act (PDCA), single minute exchange of die (SMED), A3 reporting, visual management

Tools for improving quality and delivery, selecting the most appropriate improvement tool to tackle a problem.

LO4 **Communicate the challenges and benefit of lean techniques in the workplace**

Communication:

Role and importance of continuous, open communication at all levels in the effective application of lean approaches: accepting change as the norm, reporting and commenting at all levels, treating information as the key to improvement

Role of the small work group in implementing lean principles: how regular and effective meetings can identify local problems, solutions and more general improvements

Factors that influence engagement within a group: honesty, common goals, allowing all members to contribute, valuing contributions equally, listening, keeping focused, effective questioning and non-aggressive responses, importance of keeping to time and timely feedback.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the common principles of lean manufacturing and how the implementation of a lean production system contributes to workplace efficiency		**D1** Evaluate the main challenges facing a company adopting lean operating principles for the first time
P1 Describe how lean manufacturing principles can improve company efficiency and product performance **P2** Specify the role of the employee in the lean manufacturing process	**M1** Justify the benefits of adopting lean principles in a manufacturing operation	
LO2 Explore the most widely used approaches to lean manufacturing		**D2** Illustrate how TPS can be modified to suit a specified process environment
P3 Explain why Toyota developed the Toyota Production System (TPS) **P4** Detail the underpinning principles of the TPS **P5** Explore other lean production systems to compare with the TPS	**M2** Analyse alternative lean manufacturing processes to illustrate how they build on the TPS	
LO3 Review a range of the process improvement tools used within lean manufacturing		**D3** Evaluate a lean tool to be applied to address a specific process improvement
P6 Review the most important process improvement tools associated with lean manufacturing	**M3** Analyse how process improvement tools can be used to eliminate waste in a specified manufacturing process	

Pass	Merit	Distinction
LO4 Communicate the challenges and benefit of lean techniques in the workplace		**D4** Evaluate the communication requirements for a medium-sized company adopting lean processes across all aspects of their manufacturing operations
P7 Outline why communication skills are so important in the implementation of lean principles **P8** Specify the particular communications skills required to ensure effective small group work	**M4** Analyse how good communication skills can reduce the impact on individuals and organisations facing change	

Recommended Resources

Textbooks

BICHENO, J. and HOLWEG, M. (2009) *The Lean Toolbox*. 4th ed. 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.

Websites

lean-manufacturing-japan.com	Lean Manufacturing Japan (General Reference)
www.lean.org	Lean Enterprise Institute (General Reference)
www.leanmanufacturingtools.org	Lean Manufacturing Tools (General Reference)
www.leanproduction.com	Lean Production (General reference)

Links

This unit links to the following related units:

Unit 13: Sustainability and the Environment in the Manufacturing Industry

Unit 22: Introduction to Manufacturing Systems Engineering

Unit 29: Quality and Process Improvement

Unit 12: Monitoring and Fault Diagnosis of Engineering Systems

Unit code K/617/3931

Unit level 4

Credit value 15

Introduction

This unit provides students with the opportunity to learn and apply a range of techniques to monitor and improve reliability, and diagnose faults, in engineering systems.

Engineering systems regularly use condition monitoring and quality control techniques to proactively detect symptoms of potential failure in engineering systems. The techniques used range from fully automated monitoring to human interpretation of system behaviour. The unit develops students' understanding of engineering system monitoring processes, fault diagnosis techniques and how digital techniques have improved quality control, reliability and responsiveness to environmental issues.

Health and Safety in the workplace is a serious matter and the unit gives students a clear understanding of the necessary precautions to be taken to protect themselves and others. The unit focuses on the safety measures needed when carrying out monitoring and fault-finding activities, especially those for isolation and protection.

Students will gain an understanding of condition monitoring equipment and the skills required to carry out systematic fault finding on engineering systems. They will develop the ability to select and set up monitoring equipment appropriate to the system being investigated. A variety of fault diagnosis and test techniques will be discussed. Students will learn how to use diagnostic aids to solve problems on the system under investigation.

Learning Outcomes

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

1. Define Health and Safety requirements relevant to monitoring and fault diagnosis of engineering systems
2. Explain how system monitoring technology has been developed within engineering systems to improve quality and reliability of outputs
3. Outline a range of monitoring and test equipment within an engineering environment
4. Apply a range of fault diagnosis techniques to engineering systems.

Essential Content

LO1 **Define Health and Safety requirements relevant to monitoring and fault diagnosis of engineering systems**

Legislation: appropriate statutory acts and regulations in place, nationally and internationally.

UK regulations: Health and Safety at Work Act, Management of Health and Safety Regulations, Provision and Use of Work Equipment Regulations (PUWER), Control of Substances Hazardous to Health (COSHH) Regulations, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR), Lifting Operations and Lifting Equipment Regulations, Manual Handling Operations Regulations, Personal Protective Equipment at Work Regulations, Confined Spaces Regulations, Electricity at Work Regulations, Control of Noise at Work Regulations, Health and Safety (First Aid) Regulations.

Health and Safety Organisations, e.g.: British Safety Council, Health and Safety Executive, Health and Safety Authority, Institution of Occupational Safety and Health and Safety (IOSH); European Agency for Safety and Health at Work.

International standards: ISO 45001 on Occupational Health and Safety Management Systems, managed by IOSH; International Labour Standards on Occupational Safety and Health, managed by the International Labour Organisation (ILO).

International/European regulations, e.g.: European Union directives, e.g. Waste Electrical and Electronic Equipment (WEEE) directive, Restriction of Hazardous Substances (RoHS) directive.

Specific safety requirements, e.g.: company rules, permit to work procedures, risk assessments, environmental issues.

Health and Safety procedures, e.g.: response to alarms, use of safety equipment, reporting of accidents, reporting of hazardous items of plant or equipment.

Personal safety: appropriate dress, protective clothing, appropriate or protective headgear, protective gloves and footwear, eye protection, face masks and respirators, appropriate use of barrier creams, personal cleanliness, prompt attention to injuries.

Workplace Hazards, e.g.: compressed air, hydraulic fluid, gases, hot surfaces, electrical equipment, unfenced machinery, toxic substances and fumes, falling objects, liquid spillage, untidy work area, badly maintained tools and test equipment.

Safe working practices, e.g.: isolation procedures, methods of immobilising equipment, precautions to be observed when operating or working on live equipment, permit to work, use of danger tags, warning notices, safety barriers, cones and tapes.

Engineering systems: process monitoring and control; fault diagnosis; types of systems - mechanical, fluid power, electrical, process control, environmental systems (such as fume extraction or air conditioning).

LO2 **Explain how system monitoring technology has been developed within engineering systems to improve quality and reliability of outputs**

Monitoring terminology: condition monitoring methods, offline portable monitoring, sampled monitoring, continuous monitoring, protection monitoring, human sensory monitoring.

Monitoring techniques, including: vibration analysis, temperature analysis, flow analysis, particle analysis, crack detection, leak detection, pressure analysis, voltage/current analysis, thickness analysis, oil analysis, corrosion detection, environmental pollutant analysis.

Failure and reliability: calculations concerning failure, types of failure - catastrophic, intermittent and reduction in performance failures, causes of failure, failure rate, failure modes, functional failure, primary and secondary functions, mean time between failures (MTBF).

Reliability, factors affecting reliability.

Aspects of design for failure/repair, operation, environment and manufacture, reduction in system/device failure, maintenance and routine servicing, adjustments; use of data in defects examination, statistical process control (SPC), Quality Assurance; confidence levels.

LO3 **Outline a range of monitoring and test equipment within an engineering environment**

Monitoring and test equipment:

Use of fixed and portable monitoring equipment for on and offline monitoring, including continuous and semi-continuous data recording, e.g.: vibration monitoring of bearings, self-diagnostics (such as PLCs/smart sensors, computerised data acquisition, data logging, electrical data, gas analysis).

Use of handheld instruments, e.g. meters, thermal imaging.

Use of test equipment for taking measurements of parameters, e.g. temperature, pressure, viscosity, speed, flow, voltage, current, resistance, sound, vibration.

Procedures: non-destructive testing; practical methods, e.g. crack detection, leak detection, corrosion detection, flow analysis, vibration analysis, pressure analysis, X-ray.

LO4 **Apply a range of fault diagnosis techniques to engineering systems**

Diagnostic terminology and techniques: terminology (definitions and explanations of symptoms, faults, fault location, fault diagnosis and cause); techniques such as six-point, half-split, input–output, emergent problem sequence, functional testing, injection and sampling, unit substitution

Diagnostic aids: test and measuring equipment; other aids, e.g. plant personnel, manufacturers' manuals, system block diagrams, circuit and schematic diagrams, data sheets, flow charts, maintenance records/logs, self-diagnostics, software-based test and measurement, trouble-shooting guides.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Define Health and Safety requirements relevant to monitoring and fault diagnosis of engineering systems</td><td rowspan="2">D1 Evaluate how documentation is used to identify risks and hazards in the workplace</td></tr>
<tr><td>P1 Define the aspects of Health and Safety legislation that apply to monitoring and fault diagnosis of an engineering system

P2 Describe the workplace hazards and safe working practices relevant to given fault diagnosis situations</td><td>M1 Analyse three statutory acts and regulations covering Health and Safety in the UK (or country of residence)</td></tr>
<tr><td colspan="2">LO2 Explain how system monitoring technology has been developed within engineering systems to improve quality and reliability of outputs</td><td rowspan="2">D2 Evaluate the criteria used to justify multiple test points in complex engineering systems requiring condition monitoring</td></tr>
<tr><td>P3 Explain a condition monitoring technique that could be used in a given engineering process

P4 Calculate the failure rates for a range of components, using given data from an engineering process

P5 Describe the factors affecting the reliability of a given engineering system</td><td>M2 Analyse the environmental conditions that could lead to the early failure of an engineering system and suggest methods to mitigate their effect</td></tr>
</table>

Pass	Merit	Distinction
LO3 Outline a range of monitoring and test equipment within an engineering environment		**D3** Evaluate the implications of a fault occurring in a condition monitoring circuit giving false readings
P6 Outline suitable monitoring and test equipment for continual measurement of a given system parameter **P7** Describe an investigation required when a condition monitor has recorded an increased temperature (or other parameter) within an engineering system	**M3** Analyse the limitations of a typical condition monitoring equipment	
LO4 Apply a range of fault diagnosis techniques to engineering systems.		**D4** Evaluate fault conditions within an engineering system and distinguish between symptoms, faults and causes
P8 Identify three different fault-finding techniques that could be used to diagnose a fault on an engineering system	**M4** Demonstrate a logical approach to given fault-finding exercises	

Recommended Resources

Textbooks

BIRD, J.O. and ROSS, C.T.F. (2015) *Mechanical Engineering Principles*. 3rd ed. Abingdon: Routledge.

HUGHES, P. and FERRETT, E. (2015) *Introduction to Health and Safety at Work*. 5th ed. Amsterdam: Elsevier.

Links

This unit links to the following related units:

Unit 19: Engineering Plant Operations and Maintenance

Unit 28: Instrumentation and Control Systems

Unit 30: Maintenance Engineering

Unit 13: Sustainability and the Environment in the Manufacturing Industry

Unit code A/617/3934

Unit level 4

Credit value 15

Introduction

The challenges arising from a desire to live and work in a sustainable environment are confronting us now as never before. This is being felt across all industries and aspects of life with resources such as food, water, energy and even source materials becoming ever more precious.

Climate change is a scientifically attested phenomenon, with many international government agencies acting to reverse its impact. Furthermore, there is now an increased awareness, and indeed urgency, being felt on a communal level regarding our treatment of the planet. This has clear implications for the way we use our natural resources and how we manage the life cycles of our manufactured products. For instance a common theme, increasingly vocalised, relates to ocean health, as heightened awareness of the damage caused by our discarded waste becomes evident. An awareness of these issues, particularly in relation to resources, energy consumption, reuse, life cycle analysis and post-life management, is key. A deeper understanding of the issues at play is also necessary, as is the need to avoid vilifying certain materials without a fuller analysis of the potential role they can play in supporting sustainability.

The aim of this unit is to equip the student with a wide range of knowledge and understanding of the issues and topics associated with sustainability, particularly in terms of materials, energy, consumerism and manufacture/design. The students will be introduced to lean practice, relevant legislation and practices to mitigate environmental impact including waste management and recycling.

Note regarding delivery of this unit: This unit has been designed to consider the use of materials across a range of manufacturing sectors, including, but not limited to, the automotive, food and drink, and textile manufacturing industries. The *Essential Content* section has been designed to be intentionally broad; however it is for individual Centres to focus on the relevant material types for a particular manufacturing sector. The use of e.g. within the *Essential Content* allows for Centres to select and focus on particular areas of delivery.

Learning Outcomes

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

1. Investigate material sources in terms of their sustainability and environmental impact
2. Explore the energy resources currently available and the potential of renewable energy as an alternative to traditional sources
3. Explore the rise in consumerism, what drives it and its impact on society and the environment
4. Justify the design for a sustainable product in terms of its manufacture, finishing, working life and post-life disassembly, recycling or repurposing.

Essential Content

LO1 **Investigate material sources in terms of their sustainability and environmental impact**

Source material from a range of sectors, including crops utilised as raw material for industry, e.g.:

Wood for paper and similar products, cotton for textiles, linen, silk, rubber, leather, biomaterials for plastics, biomass for fuel, coir, hemp, cereals/vegetables/fruits/nuts and other products for the food industry.

Mined materials, e.g.:

Salt, minerals and ores, coal, oil and gas, clays, potash (for fertiliser).

Animal husbandry:

Rearing of animals and their impact on the environment

Depletion of pasture lands as a result of monocultures for livestock feed

Methane emissions from animal husbandry

Environmental impact of leather processing.

Other factors to consider:

Analysis of resources and reserves using McKelvey Diagrams

Water usage

Land use/overuse and the acquisition of virgin land; changes in land use (switching of crops e.g. rubber trees to palm oil production); salinisation of land

Carbon footprint in the production and delivery of materials

Seasonality

Conversion of raw material to a state required by industry (e.g. ore to metal, wheat to flour) considering aspects such as energy and water demands.

LO2 **Explore the energy resources currently available and the potential of renewable energy as an alternative to traditional sources**

Traditional resources, including gas and oil, coal and nuclear, looking at:

Impact of extraction from its source for conversion into usable energy

Resultant emissions, and implications for whether sustainable

Water and land usage

Safety aspects including disposal of waste products

Renewable resources, including hydroelectric, tidal, geothermal, ocean energy, biomass, bio-methane, solar, wind, wood and/or waste incineration, looking at:

Water usage

Land usage

Emissions

Sustainability and consistency of supply.

LO3 **Explore the rise in consumerism, what drives it and its impact on society and the environment.**

Consumer items, e.g.: automobiles, clothing, white goods, food items, leisure equipment

Economic materialism: impact of business models based on over-consumption (e.g. buy-one-get-one-free/BOGOF); impact of growth-based economic models on the environment; consideration of different economic models and their potentially different impacts

Overproduction: causes of, and incentives for, overproduction; role of cost and price factors in overproduction; approaches that could ensure production is tailored and limited to need

Single-use products: most often referring to plastics but can relate to other materials such as aluminium foil or foiled/waxed cardboard; typical items include drinks bottles and cartons (paper/plastic), coffee cups (paper/plastic), food cans; technologies for producing lower-impact, disposable or biodegradable single-use products

Imparting desirability to a product through the use of such devices as: advertising, psychology, price strategies

Factory waste, over-production and rejects/by-products, e.g.: the destruction of garments that are deemed out of season; food products rejected when past best-before or sell-by date; scrap material formed during manufacture (e.g. runners/sprues in plastic production or risers in metal casting), metallic swarf from machining operations

LO4 **Justify the design for a sustainable product in terms of its manufacture, finishing, working life and post-life disassembly, recycling or repurposing.**

Techniques or practices, e.g.: conducting due diligence with respect to ethical practice when contracting suppliers; lean practice in operations, packaging and logistics, to reduce waste and carbon footprint; looking at life cycles of products and processes to create circular systems that redeploy by-products

Paradigm shifts in production, e.g.: the introduction of electric cars, bio-buses, solar recharging devices

Designing to avoid waste: lean practices to improve efficiency; strategic planning to meet demand without overproduction; looking at whole life cycle of a product, including end-of-life disposal; closing the circle so that materials can return to the system

Designing for sustainability such as: products manufactured with a view to dis-assembly, recycling, remoulding, repurposing, repair

Design to minimise energy use in terms of: production, working life, maintenance, repair

Disposal to avoid landfill or incineration, including: use of materials that can be disassembled, repurposed and/or recycled.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Investigate material sources in terms of their sustainability and environmental impact		**LO1 and LO2** **D1** Evaluate material and energy choices that appear vital in a given manufacturing process and suggest alternatives or ways of eliminating this process over time
P1 Assess the availability of the raw material required for production **P2** Explain the environmental impact in acquiring this material	**M1** Report possible pitfalls in the continued use of this material	
LO2 Explore the energy resources currently available and the potential of renewable energy as an alternative to traditional sources		
P3 Explain the energy requirements for a sector of the manufacturing industry **P4** Outline alternative sources of energy for a sector in the manufacturing industry	**M2** Analyse the viability and sustainability of the alternative sources cited, including factors such as assured supply, and contrast this with traditional energy sources	
LO3 Explore the rise in consumerism, what drives it and its impact on society and the environment		**D2** Evaluate the impact of consumerism on the environment, taking the example of a single-use product, and show how society has responded
P5 Explore the means by which a product becomes a consumer item	**M3** Analyse the drawbacks in pursuing consumerism in terms of sustainability and the environment	
LO4 Justify the design for a sustainable product in terms of its manufacture, finishing, working life and post-life disassembly, recycling or repurposing.		**D3** Evaluate operating environmental impact, operating energy, where applicable and end-of-life plan for selected product
P6 Redesign a product, identifying sustainable methods and materials **P7** Outline the finishing, or other ancillary, processes required in this design and show how they can be considered sustainable or environmentally friendly	**M4** Analyse the production, finishing and other ancillary processes specified for this design to show how they can be considered sustainable or environmentally friendly	

Recommended Resources

Textbooks

ANDREWS, J. and JELLEY, N. (2017) Energy Science: Principles, Technologies and Impacts. 3rd edn. Oxford: Oxford University Press.

BERNERS-LEE, M. (2010) *How Bad Are Bananas?* London: Profile Books.

BLACK, S. (2012) *The Sustainable Fashion Handbook*. London: Thames and Hudson.

BOYLE, G, and OPEN UNIVERSITY (2012) *Renewable Energy*. 3rd ed. Oxford: Oxford University Press.

EHRMAN, E. (2018) *Fashioned From Nature*. London: Victoria and Albert Museum.

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

FENNER, A. and AINGER, C. (2013) *Sustainable Infrastructures: Principles into Practice*. London: ICE Publishing.

HONE, D. (2017) *Putting the Genie Back. Solving the Climate and Energy Dilemma*. Bingley: Emerald Publishing.

Websites

www.carbontrust.com	Carbon Trust Carbon footprinting (General Reference)
sustainabledevelopment.un.org	United Nations Sustainable Development (General Reference)
sustainablefoodtrust.org	Sustainable Food Trust What to read in 2018? (Article)
www.unwater.org	United Nations Annual World Water Development Report (Report)
www.populationinstitute.org	Population Institute Demographic Vulnerability report Annual World Water Development Report (Report)
www.cat.org.uk	Centre for Alternative Technology Sustainable technologies including construction and land use (Report)
www.gov.uk	UK Gov Department of Energy and Climate Change (General Reference)

www.eauc.org.uk	The Environmental Association for Universities and Colleges (EAUC)/Sustainability Exchange – advice for higher education providers on sustainability (General Reference)
sustainabilityexchange.ac.uk	Sustainability Exchange (General Reference)
heacademy.ac.uk	Advance HE Education for sustainable development: Guidance for UK higher education providers (Guidance document)
www.theguardian.com	The Guardian Renewable energy (Articles)

Links

This unit links to the following related units:

Unit 1: Manufacturing Processes

Unit 11: Lean Techniques for Manufacturing Operations

Unit 21: Properties and Applications of Materials and Emerging Materials pre-Production

Unit 29: Quality and Process Improvement

Unit 14: Introduction to Plant Commissioning and Decommissioning

Unit code	**J/617/3936**
Unit level	**4**
Credit value	**15**

Introduction

The investment made by manufacturing operations in equipment and machinery (plant) is vast. The correct and efficient installation of new plant is vital to ensure operations start as soon as possible with the minimum of disruption to production. Likewise, when plant has reached the end of its useful life it must be removed and disposed of in a cost-effective and environmentally friendly way. These two processes are normally referred to as commissioning and decommissioning of plant.

The aim of this unit is to introduce the student to the planning necessary before beginning either process, the identification of any particular hazards that present special requirements beyond normal Health and Safety considerations, and the proper sequencing of work and use of specialist engineers or trades. Pre-production acceptance testing will also be covered, and issues of cost will be explored. End-of-life planning and procurement of replacement plant will be considered, as will the disposal by sale or scrapping of decommissioned plant. Proper recording of all processes will be emphasised.

On successful completion of this unit the student will be able to plan and carry out successful commissioning and decommissioning operations to the appropriate and agreed standards in an economical and environmentally friendly way.

Learning Outcomes

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

1. Review the information and regulations applicable to the planning of commissioning and decommissioning of manufacturing plant
2. Apply a commissioning or decommissioning procedure in a manufacturing operation to ensure the most efficient, cost-effective and safe method of working
3. Describe the need for, and type of, acceptance and start-up tests necessary when commissioning manufacturing plant
4. Undertake the planning and commissioning/decommissioning of manufacturing plant.

Essential Content

LO1 **Review the information and regulations applicable to the planning of commissioning and decommissioning of manufacturing plant**

Information required:

Specifications and operational schedules for plant being commissioned/decommissioned.

Equipment manufacturers' manuals, equipment-specific Health and Safety guidance, dimensions and mass of equipment being installed, company policies, production schedules, agreed timescales for process, required staff expertise, availability of staff and installation equipment required

Management of process.

Statutory regulations – the responsibility of employers and employees with regard to statutory regulations in the workplace, including:

Health and Safety at Work Act (HSWA)

Management of Health and Safety at Work Regulations (MHSWR)

Provision and Use of Work Equipment Regulations (PUWER)

Control of Substances Hazardous to Health (COSHH)

Lifting Operations and Lifting Equipment Regulations (LOLER)

Working at Height Regulations

Manual Handling Operations Regulations

Personal Protection Equipment at Work Regulations (PPE)

Confined Spaces Regulations

Electricity at Work Regulations

Control of Noise at Work Regulations

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

Construction Design and Management Regulations (CDM)

Health and Safety Executive's Approved Code of Practice (ACoP)

Health and Safety Executive guidance notes and safety signs.

Organisational safety requirements:

The responsibility of the employee for following company policies on Health and Safety

Adhering to required safety practices and routines.

Information sources:

Health and Safety Executive guidance

Manufacturers' manuals

The company's own policies and guidelines.

LO2 **Apply a commissioning or decommissioning procedure in a manufacturing operation to ensure the most efficient, cost-effective and safe method of working**

Plan procedure:

Determine operational objectives for commissioning or decommissioning

Identify Health and Safety requirements

Identify systems and services specific to site;

Determine resource requirements (human and physical)

Agree timescales and schedule process; ensure that timescales and schedules minimise disruption and possibility of lost production

Identify costs

Prepare documentation

Conduct operator training prior to commissioning

Implement communication and feedback strategy with evaluation criteria.

LO3 **Describe the need for, and type of, acceptance and start-up tests necessary when commissioning manufacturing plant**

Need for acceptance tests:

Importance of correct operation on first operational use

Acceptance tests: component test; start-up and shut-down tests; full load, part-load and steady state running; tests of malfunction warnings and alarms

Consideration of failure procedures, operator error procedures, bedding down.

Recording and evaluation:

Collection of source data; records of performance characteristics; data analysis, evaluation and feedback; corrective action.

LO4 **Undertake the planning and commissioning/decommissioning of manufacturing plant**

Planning:

Conduct commissioning/decommissioning planning and acceptance tests

Agree timescale, feedback and evaluation processes

Plan sale or disposal of decommissioned plant, e.g. scrap, re-engineering, use as development plant, environmental considerations and regulations

Observe equipment-specific Health and Safety requirements.

Commissioning/decommissioning:

Monitor adherence to plan

Take action on unavoidable deviation from plan

Conduct acceptance testing and receive feedback

Conduct sale or disposal of decommissioned plant

Complete handover documentation

Evaluate commissioning/decommissioning process on completion.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Review the information and regulations applicable to the planning of commissioning and decommissioning of manufacturing plant		**LO1 and LO2** **D1** Justify the operational objectives for a given commissioning or decommissioning requirement
P1 Detail the information, and its sources, required to prepare a commissioning or decommissioning plan **P2** Review the relevant statutory and organisational regulations for a given commissioning or decommissioning requirement	**M1** Illustrate how any commissioning or decommissioning requirement can be achieved with minimum disruption to manufacturing output	
LO2 Apply a commissioning or decommissioning procedure in a manufacturing operation to ensure the most efficient, cost-effective and safe method of working		
P3 Explain the need for detailed commissioning or decommissioning procedures prior to work starting **P4** Assess the Health and Safety requirements for given commissioning or decommissioning procedures	**M2** Design a detailed process, including Health and Safety requirements, for a given commissioning or decommissioning procedure	
LO3 Describe the need for, and type of, acceptance and start-up tests necessary when commissioning manufacturing plant		**D2** Evaluate the way in which the results of acceptance and start-up testing can be analysed
P5 Outline the purpose of post-commissioning acceptance and start-up testing **P6** Describe the full range of acceptance and start-up testing of a new piece of plant after commissioning	**M3** Discuss how operator errors associated with newly commissioned plant can be reduced or eliminated	

Pass	Merit	Distinction
LO4 Undertake the planning and commissioning/decommissioning of manufacturing plant.		**D3** Evaluate the effectiveness of given completed commissioning/ decommissioning plans
P7 Produce a commissioning or decommissioning plan for a given piece of manufacturing plant equipment	**M4** Analyse the alternative methods of disposing of decommissioned plant	

Recommended Resources

Textbooks

MOBLEY, K. (2014) *Maintenance Engineering Handbook*. 8th ed. New York: McGraw Hill.

RICHARDSON, D.C. (2013) *Plant Equipment and Maintenance Engineering Handbook*. New York: McGraw Hill.

Websites

www.soe.org.uk	Society of Operations Engineers Plant operations (General Reference)

Links

This unit links to the following related units:

Unit 15: Creating and Managing Projects in Manufacturing Operations

Unit 12: Monitoring and Fault Diagnosis of Engineering Systems

Unit 19: Engineering Plant Operation and Maintenance

Unit 15: Creating and Managing Projects in Manufacturing Operations

Unit code L/617/3937

Unit level 4

Credit value 15

Introduction

Many people, working in widely differing industries, describe themselves as project managers. It means that their expertise is in bringing together all the people, materials and processes, in the right order, at the best possible time, required to achieve a clearly defined output for a project in the most effective and economical way.

In manufacturing operations, a project can be as complex as the design and build of a new motor car, or as simple as the task of installing a new piece of equipment.

This unit introduces the student to the elements that constitute a project, the tools available to help achieve the specified outcome and the role of the project team and the project manager in the process. They will examine the criteria for the success or failure of a project, evaluate project management systems, and consider the reflective and analytical processes involved in the appraisal of the finished project. Students will also examine the need for structured organisation and responsibility; effective control, coordination and reporting; and communication and leadership within the project team.

On successful completion of the unit, students will be able to define a project, create project plans, set up the delivery of the project, execute and review the outputs, and understand the outcomes – how the project fits into the wider business planning strategy of the organisation.

Learning Outcomes

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

1. Explain the role and process of delivering projects in manufacturing operations
2. Describe the principles of project management and the tools available to assist the process
3. Specify the elements of a project plan in terms of organisation and people
4. Create a project plan for a specified outcome.

Essential Content

LO1 **Explain the role and process of delivering projects in manufacturing operations**

Project management:

Project management and the role of the project manager

Management of change

Elements of project management systems and their integration.

Project environment and the impact of external influences:

Identification of the major project phases and their importance

Nature of the work in each phase.

Success/failure criteria:

Need to meet operational, time and cost criteria

Definition and measurement of success, project scope, product breakdown structure (PBS), work breakdown structure (WBS), project execution strategy

Role of the project team

Considerations of investment appraisal, discount cash flow (DCF) and net present value (NPV).

Project process analysis:

Benefit analysis and viability of projects

Determination of success/failure criteria, project termination

Preparation of project definition report

Acceptance tests

Report (monthly) on rejects/defects and failure analysis with respect to manufacturing problems; corrective actions, including material or processing changes, improved operator training, enhanced quality controls.

LO2 **Describe the principles of project management and the tools available to assist the process**

Organisational structure:

Functional, project and matrix organisational structures

Consideration of cultural and environmental influences

Organisational evolution during the project lifecycle

Job descriptions and key roles in the project team

Influence of the project sponsor or owner, champion, manager, integrators, users and stakeholders.

Roles and responsibilities:

Planning, scheduling and resourcing techniques

Preparation of project plans

Operator training/re-certification

Monitoring and control.

Control and coordination:

Use of work breakdown structures to develop monitoring and control systems

Performance monitoring and progress measurement against established targets and plans

Project reporting

Changes in control procedures, documentation version control

Importance of cascading, communications briefing, instilling trust and confidence in others.

Leadership requirements:

Stages of team development; Belbin’s team roles; motivation and team building

Project leadership styles and attributes

Delegation of work and responsibility

Techniques for dealing with conflict; negotiation skills; chairing meetings.

Human resources and requirements:

Calculation, specification and optimisation of human resource requirements

Job descriptions

Formation of project teams

Project initiation and start-up procedures.

LO3 **Specify the elements of a project plan in terms of organisation and people**

Project management plans:

The 'why, what, how, when, where and by whom' of project management

Contract terms and document distribution schedules

Procurement

Establishing the baseline for the project.

Scheduling techniques:

Relationship between schedules

OBS and WBS; bar charts; milestone schedules; network techniques; resourcing techniques; computer-based scheduling and resourcing packages; project progress measurement and reporting techniques; staff-hours earned value and progress, 'S' curves; critical path analysis and reporting; milestone trending.

Cost control techniques:

Cost breakdown structure, resources needed

Types of project estimate, estimating techniques, estimating accuracy, contingency and estimation, bid estimates, whole-life cost estimates; computer-based estimating

Sources of information, sensitivity of cost information

Allocation of budgets to packages of work; committed costs; actual costs; cash flow; contingency management.

Performance:

Cost−performance analysis; budgeted cost for work scheduled (BCWS)

Budgeted cost for work performed (BCWP)

Concept of earned value

Actual cost of work performed (ACWP)

Cost−performance indicators.

Termination of the project:

Audit trails

Close-out reports.

Post-project appraisals:

Comparison of project output/outcome with business objectives

Process of self-reflection on project process and outputs/outcomes.

LO4 **Create a project plan for a specified outcome**

Production of a project plan:

Agreeing timescales and expected outcomes

Drafting and correcting proposals

Seeking and using expert feedback

Selecting suitable project management tools

Producing final plan

Presentation of plan

Reflective analysis of the final project plan.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the role and process of delivering projects in manufacturing operations		**D1** Evaluate the viability of a given project with particular emphasis on success/failure criteria
P1 Explain the principles of project management **P2** Describe the role of success/failure criteria in project development **P3** Detail the key elements in determining the viability of a project	**M1** Analyse the key elements in determining the viability of a project	
LO2 Describe the principles of project management and the tools available to assist the process		**D2** Evaluate the techniques available to prevent conflict in a small project team
P4 Identify the main elements of a project plan **P5** Detail the role of scheduling techniques in a project plan **P6** Describe the role of control and coordination in the delivery of a project plan	**M2** Analyse the importance of leadership in the role of the project team	
LO3 Specify the elements of a project plan in terms of organisation and people		**D3** Evaluate the effectiveness of cost and performance control methods used in a given project
P7 Specify the key elements of a project plan **P8** Describe the most important cost control methods available to manage a project plan **P9** Explain how project performance tools are used to manage a project	**M3** Analyse the most appropriate project management organisation tools for a given project	

Pass	Merit	Distinction
LO4 Create a project plan for a specified outcome.		**D4** Evaluate the effectiveness of the project plan produced in the light of expert and peer group feedback
P10 Design a project plan for a specified job within a familiar area of work	**M4** Analyse the project management tools selected to assist with the delivery and monitoring of the project plan	

Recommended Resources

Textbooks

NEWTON, R. (2016) *Project Management Step by Step*. 2nd ed. Harlow: Pearson Education.

SMITH, N.J. (2007) *Engineering Project Management*. 3rd ed. Oxford: Wiley-Blackwell.

Websites

www.apm.org.uk	Association for Project Management (General Reference)
www.cipmglobal.org	Charted Institute of Project Management (General Reference)
institute.pm	Institute of Project Management (General Reference)

Links

This unit links to the following related units:

Unit 2: Manufacturing Planning and Scheduling Principles

Unit 25: Managing a Professional Engineering Project

Unit 16: Introduction to Professional Engineering Management

Unit code	**R/617/3938**
Unit level	**4**
Credit value	**15**

Introduction

Engineers design, develop, manufacture, construct, operate and maintain the physical infrastructure and content of the human society we inhabit. The responsibilities that engineers bear for the safety of the people who use the outputs of their work, and the environment in which they operate, are enormous. Engineers must adopt a professional approach to their work, personal development and relationship with society and the environment.

This unit introduces students to the roles, responsibilities and behaviours of professional engineers, including the ethical and regulatory frameworks that exist to support and guide their work to maintain published standards.

Methods of personal and professional development will be examined, as will the role of reflection for learning and practice, the cycle of reflection and the importance of reflective writing in the process of development. The student will also be introduced to engineering and people management tools, together with the importance of effective communication techniques.

On successful completion of this unit the student will understand the demands of being a professional engineer and be able to construct a personal development plan for their career that meets the required standards for their role and the environment in which they operate.

Learning Outcomes

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

1. Describe the role of the professional engineer and the ethical and regulatory codes that govern this role
2. Demonstrate effective leadership and communication skills
3. Explore the importance of social responsibility when developing personal and professional standards in manufacturing organisations
4. Review the role of reflection, appropriate to the work of a professional engineer.

Essential Content

LO1 **Describe the role of the professional engineer and the ethical and regulatory codes that govern this role**

The role of the professional engineer:

Roles and levels of responsibility

The professional framework

Role of Chartered Engineer

Roles of Incorporated Engineer and Engineering Technician

Function of professional bodies and the Engineering Council

Legal and ethical responsibilities

Consequences of failure.

Ethical frameworks:

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

The National Society for Professional Engineers' Code of Ethics.

Regulatory bodies:

Global, European and national influences on engineering and the role of the engineer, in particular: the Royal Academy of Engineering and the UK Engineering Council

Role and responsibilities of the UK Engineering Council and the professional engineering institutions (PEIs)

Content of the UK Standard for Professional Engineering Competence (UKSPEC)

Regulation of the roles of Chartered Engineer, Incorporated Engineer and Engineering Technician.

International regulatory regimes and agreements:

European Federation of International Engineering Institutions

European Engineer (Eur Ing)

European Network for Accreditation of Engineering Education

European Society for Engineering Education

Washington Accord

Dublin Accord

Sydney Accord

International Engineers' Alliance

Asia Pacific Economic Cooperation (APEC) Engineers' Agreement.

LO2 **Demonstrate effective leadership and communication skills**

Leadership:

Leadership styles, and their effectiveness and appropriateness

Organisational ethos and culture; commitment to equality and diversity

Managing teams; participation and feedback; negotiation; human error evaluation; setting up support structures for team members; appropriateness of coaching and mentoring.

Communication skills:

Listening, non-verbal communication, clarity and brevity, friendliness, confidence, empathy, open-mindedness, respect, feedback and picking the right medium.

Communication with groups:

Group expectations; dealing with reactions and disagreements; allowing and encouraging participation; acting on agreed outcomes; negative communication; motivating disillusioned colleagues; persuasion and negotiation.

Equality and diversity

Ensuring work produced and the approach to work is inclusive and takes proper account of equality of opportunity and the diverse nature of the population.

LO3 **Explore the importance of social responsibility when developing personal and professional standards in manufacturing organisations**

Becoming a professional engineer:

Social responsibility in the engineering profession

Importance of being active and up to date with the engineering profession, new developments and discoveries

Methods of Continuing Professional Development (CPD)

Creating and managing a career plan.

LO4 **Review the role of reflection, appropriate to the work of a professional engineer**

Reflection for learning:

The difference between reflection and evaluation

Reflection for learning.

The cycle of reflection:

Reflection in action and reflection on action

How to use reflection to inform future behaviour, particularly with respect to sustainable performance.

Reflective writing:

Writing as a reflective process

The difference between a reflective log and a diary; importance of creating and regularly completing a reflective log

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

Continuing professional development (CPD):

The role of the reflective log in informing and driving CPD

Employee and employer benefits of CPD

Peer review; receiving and giving

The role of the engineering institutes in CPD

CPD planning and refining

CPD opportunities, e.g. workshops, site visits, lectures, short courses.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the role of the professional engineer and the ethical and regulatory codes that govern this role		**D1** Evaluate the effect of ethical frameworks on the day-to-day work of a professional engineer
P1 Describe the roles and responsibilities of the professional engineer within the Engineering Councils framework **P2** Identify the principal UK codes and regulations which control the work of the professional engineer	**M1** Analyse the main areas of influence exercised by the professional bodies in the UK on the work of the professional engineer	
LO2 Demonstrate effective leadership and communication skills		**D2** Evaluate the most effective methods for the coaching and mentoring of disillusioned colleagues or of a poorly performing team
P3 Demonstrate the process for effective persuasion and negotiation **P4** Outline the steps for managing effective group communications	**M2** Analyse leadership styles and effective communication skills using specific examples in an organisational context	
LO3 Explore the importance of social responsibility when developing personal and professional standards in manufacturing organisations		**LO3 and LO4** **D3** Evaluate the role of a socially responsible engineer and how the engineer can draw on a range of Continuing Professional Development opportunities
P5 Describe how social responsibility in engineering can support development in manufacturing **P6** Outline the ways in which a professional engineer can remain up to date with new developments and discoveries	**M3** Analyse the ethical standards and patterns of behaviour that apply to the engineering profession	

Pass	Merit	Distinction
LO4 Review the role of reflection, appropriate to the work of a professional engineer.		
P7 Undertake the completion of a reflective log **P8** Review the 'cycle of reflection' and its role in the effective completion of a reflective log	**M4** Analyse the benefits of continuing professional development from an employee and an employer perspective	

Recommended Resources

Textbooks

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

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

Websites

www.engc.org.uk	Engineering Council
	UK-SPEC – UK Standard for Professional Engineering Competence (General Reference)
www.ewb-uk.org	Engineering without Borders Becoming a Professional Engineer (General Reference)

Links

This unit links to the following related units:

Unit 25: Managing a Professional Engineering Project

Unit 17: Industrial Robots

Unit code L/617/3940

Unit level 4

Credit value 15

Introduction

Industrial robotics is the present and future of automated manufacturing and is an unstoppable reality. With the emergence of lighter, smarter and safer industrial robot models that are increasingly easy to interface, the demand has never been so high and is expected to grow year on year. Popular applications for industrial robots include welding, painting, assembly and materials handling. Modern industrial robots are now an integral part of cyber-physical mechatronic systems contributing to Industry 4.0 manufacturing.

The aim of this unit is for students to investigate the range, operation and benefits of industrial robots within manufacturing applications. Among the topics included are industrial robot selection, and programming and safety protocols that anticipate future developments in industrial robot technology.

On successful completion of this unit students will have an understanding of the electrical, mechanical, hydraulic and pneumatic operation of common industrial robots, how to select and program an industrial robot for a given requirement, taking account of safety considerations, and how to assess the economic future of robot technologies in manufacturing.

Learning Outcomes

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

1. Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries
2. Explain the safety standards associated with industrial robots
3. Program an industrial robot for automated process application
4. Investigate the global economic scope of industrial robots and integration into smart factories.

Essential Content

LO1 **Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries**

Types and selection:

Operational characteristics: Cartesian, cylindrical, spherical, toroidal, SCARA

Selection: number of axes; load, orientation, speed, travel, precision, environment and duty cycle parameters (LOSTPED); anthropomorphic robots

Common Brands: e.g. Fanuc, Yaskawa and ABB.

Applications:

Welding, painting, material handling, packaging, assembly, inspection, dangerous and robust working environments, repetitive tasks.

Operation and characteristics of 6-axis industrial robots:

Controller: motion controller, motor drives, power supplies, human−machine interface (HMI)

Manipulator: sensing, brakes, axis motor, effector motor, environment sensing

Tooling: grippers, types, interfaces

Axis operation: purpose of each axis, work area, reach, wrist roll, pitch and yaw motion, rotation, home position and calibration

End effectors: types of gripper tools and hands, two-jaw, vacuum and magnetic.

LO2 **Explain the safety standards associated with industrial robots**

Safety standards:

Functional Safety: IEC61508, Hazard and Risk Assessment

Robot and robot system safety: ANSI/RIA R15.06-2012, BS EN ISO 10218:2011

Cell safety features: operating envelope, space restrictions; operating safeguards, emergency stops, guarding, barriers, interlocks, light curtains, laser, two-hand controls, scanners, floor mats; barrier sizing - around, under, through, over (AUTO)

Operational modes, user interfaces.

LO3 **Program an industrial robot for automated process application**

Software:

E.g. data objects, instruction lists, BASIC, MATALB, Python, Yaskawa, MotoSim Enhanced Graphic Virtual Robot Control, ABB, RobotStudio, Fanuc Roboguide, Denso Wincaps III.

Robot application programming:

Types: joint-level, robot-level and high-level programming

Command and control: graphical user interfaces, point-n-click, scheduling software

Tasking software: drag-n-drop, specific application deployment, scripted language, lead by the nose

Online: joysticks, pendants, jogging, modifying existing positions

Computer simulation offline programming.

Controlling robots with programmable logic controllers (PLCs; see Unit 18)

Robot commands: motion, interlock and sensor

Manufacturers' languages: ABB Rapid, Kuka KRL, Yaskawa Inform.

LO4 **Investigate the global economic scope of industrial robots and integration into smart factories**

Economic scope:

Major markets: Japan, USA, China, South Korea, Germany

Application demand: automotive, electrical and electronics, metal

Robot density; impact on workforce; training of workforce.

Advances in robot technology:

Machine vision, artificial intelligence (AI), collaborative robots (cobots), edge computing, simplified integration, networked robots, cloud robotics, virtual reality robots; training of robots; role of robotics in Industry 4.0.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries</td><td rowspan="4">LO1 and LO2
D1 Evaluate the selection of a safety-compliant industrial robot system for a given manufacturing application</td></tr>
<tr><td>P1 Review the types of industrial robots and their applications within manufacturing industries
P2 Describe selection criteria for industrial robot applications</td><td>M1 Analyse the features and operation of six axis robots within manufacturing applications</td></tr>
<tr><td colspan="2">LO2 Explain the safety standards associated with industrial robots</td></tr>
<tr><td>P3 Outline the principles and methods of functional safety analysis within automated manufacturing
P4 Explain the safety criteria for robot cells within manufacturing applications</td><td>M2 Develop hazard and risk assessment for an industrial robot manufacturing system</td></tr>
<tr><td colspan="2">LO3 Program an industrial robot for automated process application</td><td rowspan="2">D2 Design, develop and test a robot program for a series of automated industrial tasks</td></tr>
<tr><td>P5 Investigate the range of programming languages and methods available for industrial robots
P6 Program an industrial robot to perform a simple task</td><td>M3 Analyse offline and online programming methods for industrial robots</td></tr>
<tr><td colspan="2">LO4 Investigate the global economic scope of industrial robots and integration into smart factories.</td><td rowspan="2">D3 Evaluate the global economics of increased robot density in smart factories and the impact on the human workforce</td></tr>
<tr><td>P7 Assess the advantages and scope of collaborative robots over traditional methods
P8 Investigate advances in industrial robot technology</td><td>M4 Analyse the benefits of artificial intelligence within industrial robotics and contribution to Industry 4.0</td></tr>
</table>

Recommended Resources

Textbooks

ENGELBERGER J.F. (2012) *Robotics in Practice: Management and Applications of Industrial Robots*. Berlin: Springer.

NAGAT F. and WATANABE, K. (2013) *Controller Design for Industrial Robots and Machine Tools: Applications to Manufacturing Processes*. Cambridge: Woodhead Publishing in Mechanical Engineering.

PERLBERG J. (2016) *Industrial Robotics*. Boston: Cengage Learning.

PIRES, J. (2006) *Industrial Robots Programming: Building Applications for the Factories of the Future*. Berlin: Springer.

Websites

www.machinedesign.com	Machine Design The difference between, Cartesian, six-axis and SCARA robots (General Reference)
www.nipponpulse.com	Nippon Pulse America Basics of servomotor control (General Reference)
www.iso.org	International Organization for Standardization Robots and robotic devices – safety requirements for industrial robots (General Reference)
www.robotics.org	Robotics Online Robotic resources, emerging markets, safety and standards (General Reference)
www.ifr.org	International Federation of Robotics Executive Summary World Robotics Industrial Robots (General Reference)

Links

This unit links to the following related units:

Unit 10: Industry 4.0

Unit 18: Programmable Logic Controllers (PLCs)

Unit 20: Mechatronic Systems in Manufacturing

Unit 18: Programmable Logic Controllers

Unit code	**Y/617/3942**
Unit level	**4**
Credit value	**15**

Introduction

The programmable logic controller (PLC) has revolutionised the automation industry. Since Richard Morley's Modicon invention at General Motors in the 1970s, the PLC has been the standard solution for industrial automation. Today PLCs can be found in everything from manufacturing equipment to vending machines, and PLC system development for automated systems is a highly specialised and demanding area of engineering.

The aim of this unit is to enable students to understand the rationale behind the use of programmable logic controllers and their applications in industry. The unit combines practical skills and knowledge in developing PLC applications from real scenarios with theoretical principles, such as communication and networking protocols.

On successful completion of this unit students will have developed an understanding of the evolution, types and applications of PLCs. They will know how to select and develop a PLC system, integrate features of functional safety based on their understanding of risk management, and evaluate the wide range of communication technologies available on modern PLCs.

Learning Outcomes

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

1. Describe the design, operation and selection of PLC systems
2. Explore Functional Safety within PLC systems
3. Develop a PLC program for an automated process system
4. Review how PLCs exchange information and process signals with other devices.

Essential Content

LO1 **Describe the design, operation and selection of PLC systems**

PLC architecture and operation:

central processing unit (CPU), data memory, program memory, speed, scan time, power supply, output current rating

Input/output (I/O) interface: digital, analogue, relay, transistors, TRIACs, opto-coupling.

PLC types and selection:

Compact, modular and rack-mounted

Distributed control systems and programmable automated controllers

PLC manufacturers.

LO2 **Explore Functional Safety within PLC systems**

Functional Safety standards

Evolution of Safety and Risk management

IEC61508 (Electrical, Electronic and Programmable Equipment)

IEC61131 (PLCs), IEC61131-3 (Languages)

IEC61511 (Process Control) IEC62061 (Machinery)

Hazard and risk assessment

Hazard and operability analysis (HAZOP)

Failure modes and effects analysis (FMEA)

Fault tree analysis (FTA)

Safety integrity levels, redundancy (back-up or failsafe).

LO3 **Develop a PLC program for an automated process system**

Logic control circuits

AND, OR, NAND, NOR, XOR, combinational logic, latching circuits.

Number systems

Binary, decimal, hexadecimal, octal number representation and conversion.

Memory: bits, bytes, nibbles, word, long/double

Signed and unsigned values.

PLC programming

Industrial Standard IEC61131; PLC software tools

Ladder logic operation: rungs, input, process, output

Variables: Boolean, integer, floating point

Inputs, outputs, delay functions, timers, counters, latches, registers, comparison blocks, math operators, function blocks, simulation, debugging, hardware testing, fault finding.

Documentation

Requirements and specification, flow chart, functional chart, sequence table, input/output or allocation list, wiring diagram, test data.

LO4 **Review how PLCs exchange information and process signals with other devices**

Digital communication basics

Digital versus analogue communication: analogue to digital conversion (ADC), digital to analogue conversion (DAC)

Sampling rate, resolution, errors

Noise: decoding, encoding, pulse code modulation (PCM)

Elements of a digital communication system; digital communication medium.

PLC communication and networking

Fieldbus, profibus, modbus, ethernet, profinet

OSI model, RS232, RS485, USB, parallel, serial

Controlled area network (CAN)

Supervisory control and data acquisition (SCADA)

Remote terminal unit (RTU)

Human–machine interface (HMI).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the design, operation and selection of PLC systems		**D1** Justify the selection of a programmable logic controller for a given application
P1 Describe the architecture and operation of programmable logic controllers **P2** Compare the design and applications of Compact, modular and rack-mounted PLCs **P3** Describe the range of input/output devices and PLC interface techniques	**M1** Analyse the suitability of programmable logic controllers (PLCs) with programmable automation controllers (PACs) for given applications	
LO2 Explore Functional Safety within PLC systems		**D2** Evaluate functional safety and the integration of functional safety within PLC systems to minimise hazards and risks
P3 Explore the requirement of functional safety within industrial PLC systems **P4** Compare the range of IEC6113-3 languages and their applications	**M2** Apply functional safety analysis on a PLC based automated process system.	
LO3 Develop a PLC program for an automated process system		**D3** Evaluate the PLC program for an automated process system and make justifiable modifications
P5 Translate a digital logic control circuit into an equivalent PLC program **P6** Produce design and planning documentation associated with the preparation of a PLC program **P7** Design and develop a functionally safe PLC program for an automated process system	**M3** Apply methods of testing and debugging hardware and software in PLC systems	

Pass	Merit	Distinction
LO4 Review how PLCs exchange information and process signals with other devices.		**D4** Evaluate Fieldbus and Ethernet Technologies for industrial manufacturing applications
P8 Describe the characteristics and methods of digital data communication for PLCs **P9** Review common communication technologies available on a range of PLCs	**M5** Assess the use and integration of SCADA and HMI’s with PLCs in industry	

Recommended Resources

Textbooks

BOLTON, W. (2015) *Programmable Logic Controllers*. 6th ed. Amsterdam: Newnes.

PETRUZELLA, F.D. (2010) *Programmable Logic Controllers*. New York: McGraw Hill Education.

Websites

library.automationdirect.com	Library Automation Direct
	History of the PLC
	Industrial ethernet or fieldbus network (General Reference)
www.iec.ch	International Electrotechnical Commission IEC61508 Standard, IEC61131 Standard (General Reference)

Links

This unit links to the following related units:

Unit 10: Industry 4.0

Unit 17: Industrial Robots

Unit 20: Mechatronic Systems in Manufacturing

Unit 19: Engineering Plant Operations and Maintenance

Unit code	**D/617/3943**
Unit level	**4**
Credit value	**15**

Introduction

Modern manufacturing industries require complex and costly equipment which must be operated and maintained at maximum efficiency with the minimum amount of lost production due to breakdown or routine maintenance. Properly scheduled inspection and maintenance are vital to detect problems or prevent them before they occur.

This unit will examine ways in which inspection and maintenance can be scheduled and operated; the influence of statutory and organisational regulations; the importance of safe working; and appropriate maintenance techniques. The importance of data collection and analysis to ensure maximum system performance will also be investigated.

On successful completion of this unit the student will be able to explain the importance and operation of a range of maintenance schedules and techniques, as well as techniques for data collection and analysis to assess system performance.

Learning Outcomes

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

1. Describe the importance of scheduled inspection and maintenance for the efficient operation of modern manufacturing operations
2. Demonstrate the importance of safe working and adherence to statutory and organisational regulations in minimising accidents and equipment down time
3. Assess the effectiveness of a range of inspection and maintenance schedules and techniques in given plant operations
4. Apply data collection and analysis techniques to assess system performance and maximise operational efficiency.

Essential Content

LO1 **Describe the importance of scheduled inspection and maintenance for the efficient operation of modern manufacturing operations**

Need for scheduled inspection and maintenance:

Definition of, and need for scheduled inspection and maintenance

Benefits: production efficiency, extended operating life, increased uptime, reduced downtime, increased mean time between failure.

Types of maintenance:

Planned, preventative, predictive, scheduled, unscheduled, corrective and emergency.

Scheduling and monitoring:

Importance of dead time scheduling, manual and automated recording systems, built-in maintenance notification, lock-out systems.

LO2 **Demonstrate the importance of safe working and adherence to statutory and organisational regulations in minimising accidents and equipment down time**

Working safely:

Rules for employee safety, use of safety devices and guards, lock out, tag out, electrical safety fall protection

Development and implementation of safe schemes of work

Permit to work, lone working and emergency procedures

Use of control measures (ERIC – SP)

Purpose of risk assessment and method statements for maintenance procedures.

Statutory regulations – responsibilities of employers and employees with regard to statutory regulations in the workplace, including:

Health and Safety at Work Act (HSWA)

Management of Health and Safety at Work Regulations (MHSWR)

Provision and Use of Work Equipment Regulations (PUWER)

Control of Substances Hazardous to Health (COSHH)

Lifting Operations and Lifting Equipment Regulations (LOLER)

Working at Height Regulations

Manual Handling Operations Regulations (MHOR)

Personal Protection Equipment at Work Regulations (PPE)

Confined Spaces Regulations

Electricity at Work Regulations

Control of Noise at Work Regulations

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

Construction Design and Management Regulations (CDM)

Health and Safety Executive's Approved Code of Practice (ACoP)

Health and Safety Executive guidance notes and safety signs

Organisational safety requirements - the responsibility of the employer and employee with regard to organisational safety requirements, including:

Responsibility of the employee for the safety of self and others; safety groups, informal discussion or presentation that focus on various safety issues, e.g. Safety Share, Toolbox Talk, Tailgate, Tailgate Safety Meeting, Safety Moments

Company policies on Health and Safety, setting out practices/routines to ensure all relevant regulations are met and everyone operating or maintaining machinery is safe

Developing a safety culture

The role of the Health and Safety Executive (HSE) and the power of inspectors/right of inspection; improvement notices and prohibition notices.

LO3 **Assess the effectiveness of a range of inspection and maintenance schedules and techniques in given plant operations**

Maintenance strategies:

Determination of operational objectives

Predictive component failure, bathtub curve, equipment design life and requirements for periodic maintenance

Reactive, preventative, predictive and reliability-centered maintenance; comparison of presented maintenance programmes

Maintenance schedules, resource requirements and costs, documentation, maintenance procedures against prepared criteria.

Maintenance techniques:

Importance of isolation and making safe before undertaking maintenance

Adherence to Permit to Work process and shift changeover procedures

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

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

'Look, listen and feel' approach

Visual inspections

Electrical and mechanical measurements; mechanical operations test

Functional tests, e.g. switching mechanisms.

LO4 **Apply data collection and analysis techniques to assess system performance and maximise operational efficiency**

Data collection:

Types of data collection and recording

Relevance and reliability of data sources

Determination of data parameters

Methods of data collection

Automation of data collection

methods of data recording.

Data analysis:

Comparison of collected data with published/expected outputs of the system under scrutiny

Recognition of steady-state data and intervention points

Automated analysis and alarm systems

Comparison of recorded data with operational objectives

Remedial responses to analysed data – maintaining production capability.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Describe the importance of scheduled inspection and maintenance for the efficient operation of modern manufacturing operations</td><td rowspan="2">D1 Evaluate the consequences of poor maintenance to the efficiency of manufacturing operations</td></tr>
<tr><td>P1 Identify the reasons why scheduled inspection and maintenance are essential in manufacturing operations

P2 Describe the types of maintenance associated with engineering operations</td><td>M1 Analyse ways in which maintenance can be completed without interrupting manufacturing operations</td></tr>
<tr><td colspan="2">LO2 Demonstrate the importance of safe working and adherence to statutory and organisational regulations in minimising accidents and equipment down time</td><td rowspan="2">D2 Evaluate the effectiveness of the methods used to deal with identified hazards in given workplace situations</td></tr>
<tr><td>P3 Describe the key features of Health and Safety and safe working applicable to conducting effective maintenance

P4 Demonstrate methods used to identify risks and their associated hazards</td><td>M2 Analyse the responsibilities of employees in maintaining a safe working environment</td></tr>
<tr><td colspan="2">LO3 Assess the effectiveness of a range of inspection and maintenance schedules and techniques in given plant operations</td><td rowspan="2">D3 Evaluate the maintenance requirements and techniques of a given manufacturing operation</td></tr>
<tr><td>P5 Assess the range of maintenance strategies applicable to manufacturing operations

P6 State the most applicable maintenance techniques for a given manufacturing operation</td><td>M3 Justify the importance of keeping accurate records of completed maintenance</td></tr>
</table>

Pass	Merit	Distinction
LO4 Apply data collection and analysis techniques to assess system performance and maximise operational efficiency		**D4** Evaluate data and analysis from a given set of information and suggest the most appropriate action to be taken to prevent equipment breakdown
P7 Outline the most important data collection methods applicable to a manufacturing operation **P8** Apply data collection and analysis techniques for a given manufacturing operation and present data	**M4** Analyse given data to identify steady state operation and points of intervention	

Recommended Resources

Textbooks

MOBLEY, K. (2014) *Maintenance Engineering Handbook*. 8th ed. New York: McGraw Hill.

RICHARDSON, D.C. (2013) *Plant Equipment and Maintenance Engineering Handbook*. New York: McGraw Hill.

Websites

www.soe.org.uk	Society of Operations Engineers Plant Maintenance (General reference)
www.imeche.org	Institute of Mechanical Engineers (General reference)
www.hse.gov.uk	Health and Safety Executive (General reference)

Links

This unit links to the following related units:

Unit 12: Monitoring and Fault Diagnosis of Engineering Systems

Unit 14: Introduction to Plant Commissioning and Decommissioning

Unit 30: Maintenance Engineering

Unit 20: Mechatronic Systems in Manufacturing

Unit code	**K/617/3945**
Unit level	**4**
Credit value	**15**

Introduction

Mechatronic systems are a fusion of different engineering disciplines including electrical, electronic and mechanical engineering, and control and computer systems engineering. This integration of technologies enables greater automation in manufacturing, leading to time saving, increased output and cost savings. Examples of mechatronic systems include integrated automated production lines; measuring, testing and calibration systems for quality control; and closed-loop control systems for process optimisation.

Topics within this unit include the evolution, design and characteristics of mechatronic systems; sensors, transducers and actuators; closed-loop feedback systems; programmable control devices; interfacing; system integration design; and functional safety requirements.

On successful completion of this unit students will be able to explain the design and operational characteristics of a mechatronic system, identify and apply a range of sensors, transducers and actuators, evaluate programmable control devices and design an integrated mechatronic system for a manufacturing specification.

Learning Outcomes

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

1. Explain the design and operational characteristics of a manufacturing mechatronic system
2. Investigate a range of mechatronic system components and technologies
3. Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system
4. Design a mechatronic system for a manufacturing application.

Essential Content

LO1 **Explain the design and operational characteristics of a manufacturing mechatronic system**

Origins, evolution and applications:

History and early development; evolution from purely mechanical to integrated mechatronic systems

Industrial robots and alternative applications, e.g. vehicle driver assistance systems, medical applications, domestic goods, space exploration, sports and leisure systems

Elements of a mechatronic system:

Physical system modelling; sensors and actuators; control and feedback signals; data acquisition and processing; computerised control; overview of open and closed-loop control systems

Mechatronic system integration:

Conventional systems versus mechatronic systems for manufacturing and inspection stages; high-performance versus lower cost; interpreting system requirements; understanding system constraints; selection and placement of sensors; interface matching; reliability and safety

LO2 **Investigate a range of mechatronic system components and technologies**

Analogue and digital signals:

Continuous versus discrete signals; voltage (0-10 v) versus current (4-20 mA)

Amplification and attenuation, sources of noise, filtering, Analog-to-Digital Converter (ADC) resolution, pulse width modulation

Sensors and transducers:

Temperature, light level, force, pressure, speed, position, proximity, sound, flow, humidity, vibration, voltage, current

Interpreting data sheets; selection criteria; calibration and testing

Actuators:

Types: linear, rotary, hydraulic, chain, pneumatics

Applications: valves, motors, servomechanism (servo), micro-positioning motors

Interpreting data sheets; selection criteria; mounting, force, torque, enclosure protection

National Electrical Manufacturers Association (NEMA) and International Electrotechnical Commission (IEC) .

LO3 **Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system**

Microcomputer system architecture:

CPU, memory, data, program, input/output (I/O), data and address bus

Programmable logic controllers (PLCs):

Selection criteria: size, functionality, flexibility, performance, connectivity, security, manufacturers

Programming: IEC 61131-3 Languages, software tools

Advantages and disadvantages of PLCs

Interfacing to a mechatronic system

Microcontrollers:

Selection criteria: processor, speed, memory, power, range of I/O

Programming languages: C, C++, assembly and alternative third-party and open-source software

Software tools: debuggers, emulators, simulators

Advantages and disadvantages of microcontrollers

Interfacing to a mechatronic system

Alternative programmable control devices:

Programmable automation controller (PAC), industrial PC based robot controllers, remote telemetry units (RTU), field programmable gate array (FPGA)

Functional Safety:

International Engineering Consortium (IEC) standard IEC61508

Hazard and risk assessment (HARA)

Safety integrity levels (SILs) of programmable devices

LO4 **Design a mechatronic system for a manufacturing application**

Design methodologies:

Identification of skill sets required by team members for a mechatronic system project

Interpreting requirements to develop concept design and specification

VDI 2206 (guideline for the design of mechatronic systems): general cycle of problem solving on the micro level; the V-shaped model on the macro level

Process modules for repeating design steps; advanced design modelling and simulating system behaviour

Functional Safety:

International safety standards: ISO 13849-1, IEC 61061,2006/42/EC, IEC 618005-2

European Machinery Directive 2006/42/EC for safety-related parts of a control system (SRP/CS), integrating safety into the design process

Hazard and risk assessment: hazard and operability study (HAZOP), failure modes and effects analysis (FMEA), fault tree analysis (FTA)

Use of multi-function safety relays.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the design and operational characteristics of a manufacturing mechatronic system		**D1** Evaluate the operation of a mechatronic system within a manufacturing environment characterizing the different technologies and interfaces
P1 Describe the key elements of a mechatronic system **P2** Explain the origins, evolution and benefits of mechatronic systems in manufacturing	**M1** Analyse how system integration has transformed conventional manufacturing mechatronic systems	
LO2 Investigate a range of mechatronic system components and technologies		**D2** Evaluate types of signals used in instrumentation devices and a range of signal processing techniques used when integrating mechatronic systems
P3 Identify the types of sensors and transducers used within a manufacturing mechatronic system **P4** Identify the types of actuators used within a manufacturing mechatronic system	**M2** Justify a range of instrumentation devices for a given mechatronic system design specification	
LO3 Review the operation, selection and interfacing of programmable control devices within a manufacturing mechatronic system		**D3** Evaluate a programmable control device for a given mechatronic system application with consideration to Functional Safety
P5 Describe the characteristics of programmable logic controllers and applications within manufacturing mechatronic systems **P6** Describe the characteristics of embedded microcontrollers and applications within manufacturing mechatronic systems	**M3** Analyse the operation and interfacing of a range of programmable control devices used in manufacturing mechatronic systems **M4** Analyse the range of programming languages and software tools available for programmable control devices used within manufacturing mechatronic systems	

Pass	Merit	Distinction
LO4 Design a mechatronic system for a manufacturing application.		**D4** Justify the selection of components and technologies for the development of a manufacturing mechatronic system
P7 Interpret a set of requirements to a specification for a manufacturing mechatronic system **P8** Produce a block diagram to illustrate the design of a manufacturing mechatronic system, documenting appropriate design methodology **P9** Design a mechatronic system based on a given specification and block diagram	**M5** Assess compliance, safety and risk management issues present in the design solution	

Recommended Resources

Textbooks

BOLTON, W. (2015) *Mechatronics.* 6th ed: *Electronic Control Systems in Mechanical and Electrical Engineering*. Harlow: Pearson Education.

CLARENCE, W. de S. (2010) *Mechatronics: A Foundation Course*. Boca Raton, Florida: CRC Press.

Websites

www.inderscience.com	Inderscience Publishers
	International Journal of Mechatronics and Manufacturing Systems
	International Journal of Automation and Control
	International Journal of Mechatronics and Automation
www.controleng.com	Control Engineering
	Integrating safety into engineering into mechatronic design
	Top-down strategies for innovation in mechatronic machine engineering
	When to use multi-function safety relays
	(General reference)
www.howtomechatronics.com	How to Mechatronics
	'How it works'
	(Briefings)
www.vdi.eu	Association of German Engineers VDI-Standard VDI 2206:
	Design Methodology for Mechatronic Systems (General Reference)

Links

This unit links to the following related units:

Unit 6: Material Handling Systems

Unit 17: Industrial Robots

Unit 18: Programmable Logic Controllers (PLCs)

Unit 21: Properties and Applications of Materials and Emerging Materials Pre-Production

Unit code T/617/3947

Unit level 4

Credit value 15

Introduction

Manufacturing industries are dependent upon materials, and those working within this sector need an awareness of the materials available to them. The range is great and varied, and continually increasing as new and emerging technologies demand ever more sophisticated materials. Indeed to retain a competitive edge, the constant development of materials and their potential to be adapted, is key. So for a range of sectors, including the automotive industry, textiles, consumer goods and many other types of manufacturing, materials play a fundamental role.

For a given product to achieve its desired potential and to work effectively, it is important to select an appropriate material for its manufacture. In order to ascertain the most appropriate material, it is first necessary to understand the requirements of the product and the conditions under which it will operate. By acknowledging these desired properties, it is then possible to select the material best suited for the product.

Increasingly it is common to find that an array of several material types is necessary for even the simplest application or product. A good knowledge of how these materials behave, both independently and in conjunction with each other, and an awareness of how proprieties can be altered by treatments, processing or additives, is of prime importance to ensure the product is fit for purpose.

This unit will provide students with the necessary background knowledge to identify material types and develop an awareness of the range and potential capabilities of materials at their disposal. Students will be introduced to the structure of differing material groups and how this affects the properties, physical nature and performance characteristics of common manufacturing materials. How properties can be modified will also be addressed, as will the advances in material technology which brings new capabilities to industry.

Note regarding delivery of this unit: This unit has been designed to consider the use of materials across a range of manufacturing sectors, including, but not limited to, the automotive, food and drink, and textile manufacturing industries. The *Essential Content* section has been designed to be intentionally broad; however it is for individual Centres to focus on the relevant material types for a particular manufacturing sector. The use of e.g. within the *Essential Content* allows for Centres to select and focus on particular areas of delivery.

Learning Outcomes

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

1. Define the properties necessary for a given product to function as required under its intended service conditions
2. Review the properties of a material and show how these are affected by its structure
3. Determine the material most suited for a given application
4. Explain the methods by which a material can be modified to enhance its use for a particular application.

Essential Content

LO1 **Define the properties necessary for a given product to function as required under its intended service conditions**

Define the needs of the product in terms of properties:

Mechanical

Chemical

Electrical

Thermal

Magnetic

Optical and aesthetic properties

Colourfastness

Dye acceptance

Comfort

Value for money

Recyclability.

Define the properties in terms of their characteristics:

Hardness

Toughness

Ductility

Conductivity

Durability

Resistance to stains

Resistance to environmental factors

Insulating capability

Flammability

Resistance to fatigue or corrosion.

LO2 **Review the properties of a material and show how these are affected by its structure**

Material categories, e.g.:

Polymers: commodity plastics, engineering plastics, elastomers, bioplastics

Metals: ferrous, non-ferrous, alloys

Ceramics: glass, traditional, advanced

Composites: long and short glass-reinforced polymers, carbon-reinforced polymers, reinforced ceramics, nano-reinforcement

Natural materials: wool, cotton, hemp, coir, silk

Emerging specialist materials: aerogels, shape-memory alloys, super-hydrophilic materials, self-healing materials, multi-functional materials, biomaterials.

Material structure:

Polymers: thermoplastic, thermoset, amorphous, crystalline

Metals: crystalline structures – body-centred and face-centred cubic lattice and hexagonal close-packed structures; characteristics and function of ferrous metals; non-ferrous phase diagrams

Ceramics: molecular structure – electrostatic covalent and ionic bonding

Composites: matrix and reinforcement forms

Textiles: yarn structure – distribution of fibres within the yarn, quantity of fibres within the cross section, orientation and position of fibres, fibre length, degree of twist

LO3 **Determine the material most suited for a given application**

General factors to be considered:

Functional demands of product design

Compatibility of multiple material components in a given application, under a range of expected conditions

Recyclability of the product, particularly where multiple component parts are required

Categorisation of materials by their properties:

Physical, e.g.: thermal, optical, magnetic, electrical, handling

Mechanical and surface/environmental, e.g.: resistance to oxidation and/or corrosion, durability, resistance to damage, resistance to stains, resistance to shrinkage

Aesthetic and sensory, e.g.: colour, comfort, feel, ease of handling, fragility

The effect of secondary processes or treatments on material properties, e.g.:

Heat treatment and mechanical processes

Surface modifications, such as painting and electroplating

Service life of the product and the conditions under which it will operate, e.g.:

Durability of materials; resilience to change of temperature, moisture etc.

Repairability versus obsolescence; possibility of replacing parts

Economic factors in selection, e.g.:

Forms of supply

Cost and availability

Viability of producing the quantities required

Impact of environmental concerns, public perception and government policy/legislation on material selection, e.g.:

Procurement from sustainable sources, e.g. rainforest-friendly, fair trade; best practice in mining and raw material manufacture; carbon footprint of raw material manufacture; proposed legislation on ecocide

Packaging and whether biodegradable, recyclable or reusable

Relevant regulations on safety of products

LO4 **Explain the methods by which a material can be modified to enhance its use for a particular application**

Options available to enhance specific properties, e.g.: mechanical manipulation, processing adaptations, heat treatments, weaving techniques

Additive inclusion, e.g.: particulate fillers, reinforcements (nano-particles to long fibres), antioxidants, antiozonates.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Define the properties necessary for a given product to function as required under its intended service conditions		**D1** Evaluate any potential limitations binding this product in terms of e.g. quantities required and environmental considerations
P1 Select a relevant product; describe its features in terms of its function and/or service requirements	**M1** Analyse the functions, defined in engineering terms, required for a given product when in service	
LO2 Review the properties of a material and show how these are affected by its structure		**D2** Evaluate why the behaviour of a material is considered such an important factor when selecting a material for a given product or application
P3 Explain the properties of a given material set and show how structure influences these properties	**M3** Investigate emerging materials and suggest ways these may enhance the range of materials on offer	
LO3 Determine the material most suited for a given application		**D3** Evaluate how government policy/legislation, public opinion and environmental factors influence the selection of a material for an application
P4 Explain the properties that make a material suitable for a given product **P5** Explore how the material(s) of choice would be expected to behave in service	**M5** Analyse the considerations required when selecting a material for a given application, particularly in terms of compatibility with e.g. adjoining materials, the user, secondary treatments or processes	
LO4 Explain the methods by which a material can be modified to enhance its use for a particular application.		**D4** Evaluate material modification through the incorporation of secondary phases or using other manufacturing manipulations
P6 Define how a particular materials can be modified to enhance its behaviour to achieve a specified change in the performance of that material	**M7** Investigate the advantages of modifying a material over simply selecting another material	

Recommended Resources

Textbooks

ASHBY, M. (2016) *Materials Selection in Mechanical Design*. 5th ed. Amsterdam: Elsevier.

BLACK, J.T. and KOHSHER, R.A. (2017) *Degarmo's Materials and Processes in Manufacturing.* 12th ed. Oxford: John Wiley and Sons.

CALLISTER, W. and RETHWISCH, D. (2016) *Fundamentals of Materials Science and Engineering: An Integrated Approach*. 5th ed. Oxford: John Wiley and Sons.

Websites

nptel.ac.in	NPTEL 4.Ring Spun Yarns (General Reference)
www.textilemates.com	Textile Mates Yarn Structure Properties (General Reference)
www.americanchemistry.com	American Chemistry Council The Basics: Polymer Definition and Properties (General Reference)
www.substech.com	Substances and Technologies (General references)

Links

This unit links to the following related units:

Unit 13: Sustainability and the Environment in the Manufacturing Industry

Unit 26: Materials, Properties and Testing

Unit 32: Materials Engineering with Polymers

Unit 22: Introduction to Manufacturing Systems Engineering

Unit code	**A/617/3948**
Unit level	**4**
Credit value	**15**

Introduction

Manufacturing systems engineering is concerned with the design and on-going operation and enhancement of the elements within a manufacturing system. While this unit refers to the underlying principles of Manufacturing Systems Engineering, the sectors of particular focus are automotive, food and drink, and textile manufacture.

This unit introduces the student to the complexity of a modern manufacturing environment. The topics cover all elements that make up a manufacturing system, including: production engineering, plant and maintenance engineering, product design, logistics, production planning and control, forecast Quality Assurance, accounting and purchasing, all of which work together within the manufacturing system to create the final output.

On successful completion of this unit students will be able to describe the main elements of a modern manufacturing system and explain how existing systems can be improved through the use of measuring and acquiring data and using it to optimize the process. They will also be confident to review systems of production planning and control.

Learning Outcomes

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

1. Explain the principles of manufacturing systems engineering and their relevance to the design and development of manufacturing systems
2. Demonstrate how a range of analysis tools, including value stream mapping, can be used to determine the effectiveness and efficiency of a manufacturing system
3. Outline the impact of different production planning approaches on the effectiveness of a manufacturing system
4. Assess the impact of manufacturing systems engineering on a manufacturing operation.

Essential Content

LO1 **Explain the principles of manufacturing systems engineering and their relevance to the design and development of manufacturing systems**

Underpinning principles of manufacturing systems engineering:

Making the production process as efficient as possible

Importance of continuous analysis, research and development of the process

Manufacturing systems control elements:

Quality, cost, delivery performance and optimisation of output

Development and management of manufacturing systems:

Problem solving, maintenance scheduling and planning, resource planning and productivity

Effect of testing and data analysis on system performance

LO2 **Demonstrate how a range of analysis tools, including value stream mapping, can be used to determine the effectiveness and efficiency of a manufacturing system**

Analysis tools:

Introduction to value stream mapping; the value of both current state mapping and future state mapping

Bottle-neck analysis, using process improvement tools and techniques (value stream analysis, simulation, Kanban)

Using key performance indicators (KPIs) to understand the performance of a manufacturing system:

Overall equipment effectiveness, lead time, cycle time, waiting time, yield, delivery performance, safety metrics

Reviewing key performance indicators

Methods for presenting metrics and performance (balanced scorecards, performance dashboards, Andon boards, Gemba walks)

LO3 **Outline the impact of different production planning approaches on the effectiveness of a manufacturing system**

Production planning approaches:

Examples of production planning strategy: push versus pull factors, Kanban systems, make to stock, make to order and engineer to order, just-in-time (JIT) production, modular design, configuration at the final point, and master scheduling

Production planning management tools:

Enterprise resource planning (ERP) systems, material resource planning (MRP 2) and manufacturing execution systems; ability to manage complexity and resourcing through information technology

Industrial engineering issues:

The importance of standard time manufacturing and the impact on productivity and the costing of products

How standard work underpins the repeatability of process and quality control

LO4 **Assess the impact of manufacturing systems engineering on a manufacturing operation**

Effectiveness of manufacturing systems:

Plant layout design, cleanliness of manufacturing and test areas, planning, work instructions and control, productivity and continuous improvement, quality control in process inspection and test, final inspection and test, equipment effectiveness.

Manufacturing information technology:

Supply of data from the process to decision makers, e.g.: failure modes for both product and system, maintenance and down-time data, standard time for production, material control, energy usage

Importance of various data sources and identification of key elements for successful manufacturing operation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the principles of manufacturing systems engineering and their relevance to the design and development of manufacturing systems		**D1** Evaluate the impact that manufacturing systems have on the success of a manufacturing organisation
P1 Describe the underpinning principles of manufacturing systems engineering **P2** Explain the role of the main control elements within manufacturing systems	**M1** Identify the main features of a development process in manufacturing systems engineering	
LO2 Demonstrate how a range of analysis tools, including value stream mapping, can be used to determine the effectiveness and efficiency of a manufacturing system		**D2** Evaluate the effectiveness of the methods available to present key performance indicators (KPI) for a given manufacturing operations application
P3 Define the main features and applications of value stream mapping **P4** Illustrate where current and future state mapping would be usefully employed within manufacturing systems	**M2** Show how equipment efficiency may be measured in a typical manufacturing application	
LO3 Outline the impact of different production planning approaches on the effectiveness of a manufacturing system		**D3** Evaluate a given production process and justify the most suitable production planning technique to improve productivity
P5 Outline the most important methods used to aid the development of production planning strategy **P6** State how standard time manufacturing impacts on productivity and the costing process	**M3** Analyse the effectiveness of production planning methods for a given process	

Pass	Merit	Distinction
LO4 Assess the impact of manufacturing systems engineering on a manufacturing operation.		**D4** Evaluate the elements of a given manufacturing operation that contribute to its success, and suggest how it might be improved
P7 Outline the principal features that contribute to the effective operation of a manufacturing process **P8** Explain how quality control and equipment effectiveness can influence the effectiveness of a manufacturing operation	**M4** Analyse the critical data required by management to ensure the most efficient operation of a manufacturing process	

Recommended Resources

Textbooks

BICHENO, J. and HOLWEG, M. (2009) *The Lean Toolbox*. 4th ed. Buckingham: PICSIE Books.

CHOPRA, S. and MEINDL, P. (2015) *Supply Chain Management: Strategy, Planning, and Operation.* 6th ed. Harlow: Pearson.

SLACK, N. (2013) *Operations Management*. 7th ed. Harlow: Pearson.

WOMACK, J., JONES, D. and ROOS, D. (1990) *The Machine that Changed the World*. New York: Free Press.

Websites

www.industryweek.com	Industry Week
	Five Benefits of MES (Article)

Links

This unit links to the following related units:

Unit 2: Manufacturing Planning and Scheduling Principles

Unit 7: Workplace Study and Ergonomics

Unit 8: Business Improvement Techniques for Engineers

Unit 11: Lean Techniques for Manufacturing Operations

Unit 15: Creating and Managing Projects in Manufacturing Operations

Unit 29: Quality and Process Improvement

Unit 23: 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

Pass	Merit	Distinction
LO1 Plan a design solution and prepare an engineering design specification in response to a stakeholder's design brief and requirements		**D1** Compare and contrast the completed design specification against the relevant industry standard specification
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	**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	
LO2 Formulate possible technical solutions to address the student-prepared design specification		**D2** Evaluate potential technical solutions, presenting a case for the final choice of solution
P4 Explore industry standard evaluation and analytical tools in formulating possible technical solutions **P5** Use appropriate design techniques to produce a possible design solution	**M3** Apply the principles of modelling, simulation and/or prototyping, using appropriate software, to develop an appropriate design solution	

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 31: Computer Aided Design and Manufacture (CAD/CAM)

Unit 24: 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 4: Manufacturing Operations Mathematics

Unit 5: Engineering Maths

Unit 21: Properties and Applications of Materials and Emerging Materials Pre

Production

Unit 26: Materials, Properties and Testing

Unit 25: Managing a Professional Engineering Project

Unit code A/615/1478

Unit type Core

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 vial 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 together with the behaviours that accompany their actions.

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

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

This unit is assessed by a Pearson-set 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 the Professional Engineering Institutions (PEIs)

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

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 adapt 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 on-going 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*. Prentice Hall.

STRIEBIG, B., OGUNDIPE, A. and PAPADAKIS, M. (2015) *Engineering Applications in Sustainable Design and Development*. Cengage Learning.

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

Journals

Journal of Engineering Design.

Links

This unit links to the following related units:

Unit 15: Creating and Managing Projects in Manufacturing Operations

Unit 16: Introduction to Professional Engineering Management

Unit 26: 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	
LO3 Explore the testing techniques to determine the physical properties of an engineering material		**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
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	**M3** Explain how test results influence material selection for a given application	

Pass	Merit	Distinction
LO4 Recognise and categorise the causes of in-service material failure		**D4** Explain the methods that could be used for estimating product service life when a product is subject to creep and fatigue loading
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	**M4** Explain, with examples, the preventative measures that can be used to extend the service life of a given product within its working environment	

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. New Jersey: Wiley Wiley.

Links

This unit links to the following related units:

Unit 21: Properties and Applications of Materials and Emerging Materials Pre Production

Unit 23: Engineering Design

Unit 24: Engineering Science

Unit 32: Materials Engineering with Polymers

Unit 27: 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. They will be able to select the most appropriate production processes and associated facility arrangements for manufacturing products of different material types and design a production system incorporating a number of different production processes.

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

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

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

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

Pass	Merit	Distinction
LO3 Analyse how a production system can incorporate a number of different production processes for a given product or assembly		**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		**D4** 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 1: Manufacturing Processes

Unit 22: Introduction to Manufacturing Systems Engineering

Unit 31 Computer Aided Design and Manufacture (CAD/CAM)

Unit 28: 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

Pass	Merit	Distinction
LO1 Identify the instrumentation systems and devices used in process control		**D1** Critically review the industrial application of an instrumentation and control process system, using research evidence
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	**M1** Explore industrial applications for sensors and transducers **M2** Analyse the accuracy of the sensors and transducers used in a particular application	
LO2 Investigate process control systems and controllers		**D2** Develop a recommendation for improvement to process control systems and controllers
P5 Describe the importance of process control systems **P6** Define the process controller terminology used in industrial applications	**M3** Explain a typical industrial application for a process control system	
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.

Links

This unit links to the following related units:

Unit 9: Dimensional Control of Complex Assemblies

Unit 12: Monitoring and Fault Diagnosis of Engineering Systems

Unit 18: Programmable Logic Controllers (PLCs)

Unit 29: 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. Oxford: Butterworth-Heinemann.

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

Links

This unit links to the following related units:

Unit 7: Workplace Study and Ergonomics

Unit 8: Business Improvement Techniques for Engineers

Unit 11: Lean Techniques for Manufacturing Operations

Unit 29: Quality and Process Improvement

Unit 30: 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 14: Introduction to Plant Commissioning and Decommissioning

Unit 19: Engineering Plant Operations and Maintenance

Unit 31: 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	

Pass	Merit	Distinction
LO4 Design and produce a dimensionally accurate component on a CNC machine using a CAD/CAM system		**D4** Critically analyse, giving illustrative examples, the different methods of data transfer through a CAD/CAM system
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	**M4** Analyse different methods of component inspection used in manufacturing	

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 23: Engineering Design

Unit 32: Materials Engineering with Polymers

Unit code	**K/616/2556**
Unit level	**4**
Credit value	**15**

Introduction

This unit will provide students with the necessary background knowledge and understanding of the structure and property relationship of polymer materials to guide their selection of material and manufacturing techniques to produce a sustainable, fit for purpose product.

Polymer products are driving innovation and research around the world and are predicted to expand further to replace traditional engineering materials in a wide variety of applications. Students will be made aware of the wide range of polymer materials at their disposal and the opportunity for using the new grades that are being developed on a daily basis.

This unit will provide students with an understanding of the relationship between a polymer's structure and properties and between processing technique and product performance. The ability to determine a polymer's properties is crucial and this unit will include a review and practical application of the main testing techniques. One of the most important skills for a manufacturing engineer is the ability to distinguish between different types of polymers. This will be developed during practical sessions that will provide students with the opportunity to carry out preliminary investigations and simple identification tests. This will be supported by an overview of the main types of polymer materials.

Inadequate consideration of a specific behavioural requirement can lead to product failure and reduced service life. This will be addressed by providing techniques for material modification and learning how to use data sources for material selection. In addition this unit will consider environmental concerns and offer solutions to reduce waste and improve sustainability.

Learning Outcomes

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

1. Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties
2. Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application
3. Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application
4. Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers

Essential Content

LO1 **Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties**

Introduction

polymer concept

definition of the main terms, e.g. monomer, repeating units

classification of polymers (natural, synthetic, organic, inorganic)

Molecular Structure

structure of polyethylene chain

chain length and molar mass;

molar mass distribution;

calculations of number (average molar mass and weight-average molar mass)

significance of molar mass to processing and performance properties of polymers

configuration of the chain molecule

confirmation of the chain molecule

secondary bonds between chain molecules

cohesion

adhesion

solubility

compatibility of polymer blends

Polymer morphology

aggregational states of matter

amorphous solid state

amorphous polymers

glass transition temperature and its significance to processing and service life crystalline polymers

melting temperature, conditions for crystallinity, effect of processing on crystallinity, morphological features (lamellae and spherulites)

LO2 **Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application**

Commodity and engineering thermoplastics

e.g. polyethylenes

modified polyethylenes; polypropylene

polyamides and aramids (overview of structure, properties and processability)

Thermosets

e.g. epoxies

phenolics; polyesthers

material storage

concept of gel-point

quantitative analysis i of cross-linking (overview of structure, properties and processability)

Rubber and elastomers

e.g. natural rubber (NR)

acrylonitlile butadiene rubber (NBR); styrene butadiene rubber (SBR), butyl rubber (BR), polychloroprene rubber (CR), ethylene propylene rubber (EPR)

introduction to vulcanisation and compounding

overview of structure, properties and processability

Introduction to simple identification tests and techniques

e.g. density, solubility

LO3 **Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application**

Criteria for material selection

definitions of material properties and characteristics

material selection flow chart

overview of selection methods e.g. structured and unstructured data; material selection charts

Material testing to determine the properties of polymers

mechanical e.g. tensile, flexural, impact

optical (colour)

electrical (conductivity/resistivity)

thermal (melting temperature, glass transition temperature)

rheological

Data sources

published data e.g. British standards, ISO, material's data sheet, IT sources, standard published data sources, manufacturers' literature

assessment of data reliability

Polymer modification

review of polymer additives and their functions

consideration of their cost and quantity in a compound formulation e.g. fillers, plasticisers, stabilisers, flame retardants, blowing agents, colourants, cross-linking and vulcanising agents

LO4 **Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers**

Premature failure of polymer products

causes of failure in polymer products e.g. visco-elastic and time-dependent behaviour of polymers, brittle and ductile failure, impact failure, creep rupture and fatigue failure, environmental effects

contributory effects of service conditions to failure e.g. faults in design and manufacture, inappropriate use, changes to service conditions such as load, time, temperature and environment

Solutions to environmental concerns

overview of relevant Government policies and Directives

acceptable waste management and disposal techniques e.g. re-use, mechanical recycling of single and mixed polymers

feedstock recycling to produce monomers, oligomers and chemical raw materials energy recovery

re-processing of polymers and its effect on processing and mechanical properties stabilisation of polymers to prevent weathering, chemical and thermal degradation

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties</td><td rowspan="4">LO1 and LO2

D1 Justify the selection of a polymer material for a given engineering application through critical analysis of its structure and properties</td></tr>
<tr><td>P1 Explain how the structure and morphology of different given polymer materials affect their processing and performance properties</td><td>M1 Calculate the molar mass of a given polymer sample, commenting on the significance of the results to processing and performance properties</td></tr>
<tr><td colspan="2">LO2 Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application</td></tr>
<tr><td>P2 Use preliminary investigations and simple identification tests to distinguish between different types of polymer materials</td><td>M2 Apply structural considerations to compare and contrast the properties and processability of these polymer materials</td></tr>
<tr><td colspan="2">LO3 Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application</td><td rowspan="2">LO3 and LO4

D2 Critically evaluate test results to justify selection of the most suitable additive or acceptable amount of recycled material in a given product</td></tr>
<tr><td>P3 Identify the required properties for a specified engineering product

P4 Evaluate data sheets to select the most appropriate materials and processing techniques for the engineering product</td><td>M3 Re-examine data sheets to extend the range of selected materials by proposing a suitable modification to the base material</td></tr>
</table>

Pass		Merit	Distinction
LO4 Recognise the limitations of polymer behaviour and potential solutions to environmental concerns associated with polymers			
P5 Explain the common causes of premature failure of polymer products **P6** Explain how polymer materials can be safely disposed or recovered through acceptable waste management techniques		**M4** Give consideration to the contributory effects of service conditions in a given product and make recommendations to prevent failure **M5** For a given product/ evaluate the potential benefit of using recycled material in place of virgin material	

Recommended Resources

Textbooks

ASHBY, M.F. and JONES, D.R.H. (2013) *Engineering Materials 2: An Introduction to Microstructures and Processing*. 4th ed. Amsterdam: Butterworth-Heinemann.

ASHBY, M.F. and JONES, D.R.H. (2012) *Engineering Materials 1: An Introduction to Properties, Applications, and Design*. 4th Ed. Amsterdam-Boston: Butterworth-Heinemann.

BRAUN, D. (2013) *Simple Methods for Identification of Plastics*. 5th Ed. Munich: Hanser.

CALLISTER, W. and RETHWISCH, D.G. (2015) *Fundamentals of Materials Science and Engineering: An Integrated Approach*. 5th ed. Hoboken, New Jersey: Wiley.

LA MANTIA, F. (2002) *Handbook of Plastics Recycling*. Shrewsbury: Rapra Technology Limited.

McCRUM, N.G., BUCKLEY, C.P. and BUCKNALL, C.B. (2003*) Principles of Polymer Engineering*. 2nd Ed. Oxford: Oxford. Univ. Press.

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www.cia.org.uk	Chemical Industries Association (General reference)
www.cogent-ssc.com	Cogent – Sector Skills Council (General reference)
www.stemnet.org.uk	Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme (General reference)

Essential Resources

Tensometer (to evaluate tensile properties of materials, such as Young's modulus)

Pendulum impact tester

Hardness tester

Controlled laboratory area for flammable tests on polymers

Links

This unit links to the following related units:

Unit 21: Properties and Applications of Materials and Emerging Materials Pre Production

Unit 23: Engineering Design

Unit 26: Materials, Properties and Testing

11 Appendices

Appendix 1: 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 either: • breaking down a theme, topic or situation in order to interpret and study the interrelationships between the parts; and/or • of information or data to interpret and study key trends and interrelationships. Analysis can be through activity, practice, 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.
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 selection of characteristics.
Compose	Create or make up or form.
Communicate	Convey ideas or information to others. Create/construct Skills to make or do something, for example a display or set of accounts.
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.
Describe	Give an account, including all the relevant characteristics, qualities and events.

Term	Definition
Discuss	Consider different aspects of: • a theme or topic; • how they interrelate; and • the extent to which they are important.
Demonstrate	Show knowledge and understanding.
Design	Plan and present ideas to show the layout/function/workings/object/system/ Process.
Determine	To conclude or ascertain by research and calculation.
Develop	Grow or progress a plan, ideas, skills and understanding.
Differentiate	Recognise or determine what makes something different.
Discuss	Give an account that addresses a range of ideas and arguments
Evaluate	Work draws 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 relationship to its context. This will often be in a conclusion. Evidence will often be written but could be through presentation or activity.
Explain	To 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 by 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; or • 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.

Term	Definition
Produce	To bring into existence.
Reconstruct	To assemble again/reorganise/form an impression.
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 & 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	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 to which all students must select and apply knowledge.
Project	A large scale activity requiring self-direction of 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 2: 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 5 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	Summative
		Written Communication	
		Initiative	
		Decision-making	
		Critical Thinking	
Simulated Activity	This technique is a multi-faceted activity based on realistic work situations.	Self-reflection	Formative
		Critical Thinking	Summative
		Initiative	
		Decision-making	
		Written Communication	
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	Formative
		Teamwork	Summative
		Leadership	
		Negotiation	
		Written and Oral Communication	
Time-constrained Assessment	This technique covers all assessment that needs to be done within a Centre-specified time constrained period on-site.	Reasoning	Summative
		Analysis	
		Critical thinking	
		Interpretation	
		Written Communication	
Top Ten	This technique asks students to create a 'top ten' list of key concepts presented in the assigned reading list.	Teamwork	Formative
		Creativity	
		Analysis	
		Collaboration	

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 3: Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations Unit Mapping against Process Leader Apprenticeship Standard

Unit	Knowledge	Skills	Behaviours
1	K1, K2, K7, K8, K17	S1, S2, S3, S6, S25	B4, B6
2	K1, K8	S1, S2, S3, S6, S11	B4, B6
3	K1, K4, K5, K6, K8, K9, K13	S1, S2, S3, S7, S8, S11, S17, S18, S25	B1, B2, B4, B6
4	K1, K17	S3, S25	B6
5	K1, K17	S3, S25	B6
6	K1, K2, K5, K7, K8, K9, K17	S1, S2, S3, S4, S6, S7, S9, S10, S11, S22, S25	B1, B2, B6
7	K1, K5, K7, K8, K9, K17	S1, S2, S3, S7, S8, S10, S21, S25	B1, B2, B6
8	K1, K4, K5, K6, K9	S1, S2, S3, S7, S8, S11, S23, S25	B1, B2, B6
9	K1, K4, K5, K6, K8	S1, S2, S3, S7, S8	B1, B4, B6
10	K1, K2, K4, K9, K11	S1, S2, S3, S17, S23, S25	B2, B3, B6
11	K1, K4, K5, K6, K9, K11, K16	S1, S2, S3, S7, S8, S11, S17, S18, S23, S25	B1, B2, B3, B4, B5, B6
12	K1, K5, K9	S1, S5, S7, S8, S9, S10	B5, B6
13	K1, K2, K7, K17,	S1, S3, S4, S22, S25	B1 B2, B4, B6
14	K1, K2, K8, K7, K9, K16	S1, S2, S3, S4, S9, S10, S11, S22, S23, S25	B1, B6
15	K1, K2, K7, K9, K13, K14, K15, K16, K17, K18	S1, S2, S3, S11, S12, S18, S19, S22, S24, S23, S25	B1, B2, B3, B4, B5, B6
16	K1, K5, K7, K11, K12, K13, K14, K15, K16, K17, K18	S1, S2, S3, S4, S5, S6, S8, S11, S12, S!3, S14, S15, S16, S17, S18, S19, S20, S21, S22, S 23, S24, S25	B1, B2, B3, B4, B5, B6
17	K1, K7, K8,	S1, S2, S3, S22, S25	B2, B6
18	K1, K7	S1, S3, S9, S25	B6
19	K1, K5, K6, K7, K8	S1, S3, S6, S9, S10, S25	B1, B4, B6
20	K1, K7, K17	S1, S2, S3, S9, S10, S11, S22, S25	B1, B2, B6
21	K1, K2	S1, S3	B1, B6
22	K1, K5, K6, K7, K8	S1, S2, S3, S6, S7, S8, S25	B1, B6
23	K1, K6, K8, K16	S3, S11, S22, S23, S25	B2, B4, B5, B6
24	K1, K17	S3, S25	B6
25	K1, K3, K9, KK16, K17, K18	S1, S2, S3, S11, S22, S23, S24, S25	B1, B2, B3, B4, B5, B6

Unit	Knowledge	Skills	Behaviours
26	K1, K8	S1, S3, S25	B6
27	K1, K4, K8	S1, S3, S25	B2, B6
28	K1, K5, K8	S1, S3, S25	B6
29	K1, K4, K5, K6, K7, K9	S1, S2, S3, S6, S7, S8, S22, S25	B1, B2, B4, B5, B6
30	K1, K5, K7, K8	S1, S2, S3, S4, S9, S22, S25	B1, B4, B5, B6
31	K1, K7, K8	S1, S3, 25	B2, B4, B6
32	K1, K6	S1, S2, S3, S9, S22, S25	B1, B2, B6

Apprenticeship Standard – Process Leader: Knowledge, Skills, Behaviours
Knowledge

K1 Principles of production/manufacturing techniques including: material handling systems, maintenance, production planning/scheduling, ergonomics, work place study, plant organisation, decommissioning, Statistical Process Control, process types such as flow and batch, product/raw material principles

K2 How to identify and procure sufficient, suitable resources (e.g. finance, staff, equipment, supplies) including use of management tools such as the Internet of Things (IoT) and Industry 4.0

K3 Budgeting, forecasting and control of direct and indirect costs, fixed and variable costs including actual, accrued and committed costs

K4 Lean operational and quality improvement practices such as workplace organisation, visual management, waste reduction and shop floor problem solving

K5 Delivery of quality management and assurance systems

K6 Problem definition: Cost of Poor Quality, problem analysis models such as Is/Is Not

K7 Safe and professional working practices including health, safety, environment and legislative requirements relevant to the sector, the organisation and own role

K8 Production procedures and regulations to meet legislative/organisational requirements

K9 Planning and project management principles, problem solving, relationship building and leading through KPIs

K10 Employment law, employee rights and responsibilities, organisation staff management policies/procedures for e.g. recruitment, performance, development, discipline, grievance, equality/diversity, industrial relations

K11 Theories of performance management and their use and organisations tools and policies for managing teams

K12 The theory of managing, motivating and developing people

K13 The purpose of organisational vision and goals and how these apply to teams

K14 Awareness of the differing strengths team members have and how these can be effectively applied in the workplace

K15 Approaches to colleague, stakeholder/ supplier relationship management including collaboration, negotiation, influencing, managing conflict, and networking [K15]

K16 How to communicate and cascade information effectively at all levels and to a diverse audience

K17 How to identify the information required for decision making, how it should be gathered and reported

K18 How to develop and present a case to management when requesting change including single page reporting

Skills

S1 Undertake and direct production activities and operations

S2 Propose, undertake, manage and coordinate changes to the product, production operations, processes and equipment, to improve productivity, efficiency and quality

S3 Solve problems - predict and prevent failures through the analysis of data and information

S4 Manage resources effectively to ensure their availability and the efficient running of department in line with organisational procedures

S5 Deliver cost achievements against budget targets

S6 Plan resources to support variations in production schedules

S7 Use KPIs as the basis of the continuous improvement cycle for quality, cost and volume achievement using lean operational and product improvement techniques

S8 Undertake and manage quality resolutions as well as volume problem resolution

S9 Manage health, safety and the environment within area of responsibility, ensuring staff are compliant with all requirements and driving improvements

S10 Conduct workplace risk assessments, manage near-miss or similar processes, conduct investigations as necessary

S11 Use project management tools to plan, organise and manage resources, to monitor progress, identify risks and mitigation

S12 Recruit the right people into the right job

S13 Develop, build and motivate teams by identifying strengths and enabling training and development within the workplace

S14 Recognise excellence, effectively manage performance, discipline, attendance, grievance

S15 Manage industrial relations and equality and diversity

S16 Support development through coaching and mentoring

S17 Leading and communicating the management of change

S18 Provide clear direction and leadership, giving open and honest feedback. Apply and adapt own leadership style to different production situations and people

S19 Delegate and enable delivery though others

S20 Build and maintain strong relationships across different disciplines. Negotiate and influence. Manages conflict

S21 Identify and share good practice, work collaboratively

S22 Utilise specialist advice and support to deliver plans

S23 Communicate effectively (verbal, non-verbal, written, digital) in manner relevant to the target audience

S24 Chair meetings and present (formally and informally) using a range of media. Listen actively, challenge, give feedback

S25 Analyse data/information to compellingly and succinctly present information to drive management decisions

Behaviours

B1 Decision Making: Makes decisions based on personal initiative, technical knowledge, analysis and understanding of the different interests of stakeholders. Accepts responsibility for decisions and recognises limit to own authority

B2 Agile: Flexible and adaptable to the needs of the organisation. Is creative, innovative and enterprising when seeking solutions to business needs. Positive and open to new ways of working, responds well to feedback and change

B3 Inclusive: Open, approachable, authentic, and able to build trust with others. Promotes a respectful culture embracing diversity and inclusion. Seeks and provides feedback to manage continuous development of self, team and processes

B4 Responsibility, Accountability and Resilience: Drive to achieve in all aspects of work. Demonstrates resilience and accountability. Determination when managing difficult situations. Seeks new opportunities

B5 Professionalism: Sets an example, and is fair, consistent and impartial. Open and honest. Operates within organisational values. Promote and instil the values of the organisation to all colleagues

B6 Problem solver: Identifies issues quickly, enjoys solving complex problems and applies appropriate solutions. Has a strong desire to push to ensure the root cause of any problem is found and solutions identified which prevent recurrence

Appendix 4: Pearson BTEC Level 4 Higher National Certificate in Manufacturing Operations Programme Outcomes for Students

	Knowledge and Understanding												Cognitive skills									Applied skills					Transferable skills														
Unit	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	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					x			x	x	x			x						x				
3	x		x		x		x					x	x	x	x	x			x				x	x		x	x	x			x						x				x
4	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				
6	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	x	x	x	x	x	x	x			x						x	x	x			x		x			x	x				x
8	x	x	x	x		x	x					x	x	x	x		x		x	x				x		x	x	x			x						x				
9	x	x		x			x					x	x		x				x					x		x	x	x			x						x				x
10	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
11	x				x		x				x	x	x		x	x			x							x	x	x			x						x	x			
12	x		x	x	x		x			x	x	x	x	x	x	x			x	x				x	x	x	x	x			x		x			x	x				
13	x	x			x		x			x	x	x	x			x			x	x				x		x	x	x			x		x			x	x				
14	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	12	1	2	3	4	5	6	7	8	9	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	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			
16	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
17	x	x	x			x					x		x		x			x	x	x			x	x		x	x			x	x		x		x		x				
18	x		x			x				x	x	x	x					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	x	x	x	x		x	x	x	x			x	x	x			
20	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			
21	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		x
22	x											x	x						x					x		x	x			x		x									
23	x											x	x						x					x		x	x			x		x									
24	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
25	x									x									x					x		x	x			x		x									
26	x												x						x				x			x	x		x												
27	x			x	x						x							x	x							x				x						x					
28	x				x					x		x				x		x	x							x		x		x						x					
29	x	x	x	x	x	x	x		x	x	x	x						x	x				x		x	x	x	x		x						x				x	
30	x	x	x				x				x	x		x				x							x	x	x			x		x			x		x		x		x
31			x	x	x		x			x		x	x			x			x					x		x			x												

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