

**BTEC**

# **HIGHER NATIONALS**

## **Engineering**

### **Specification**

First Teaching from September 2018

First Certification from 2019

**Higher National  
Certificate Lvl 4**

**Higher National  
Diploma Lvl 5**

## **About Pearson**

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## Summary of changes in Pearson BTEC Higher Nationals in Engineering Issue 7

Summary of changes made between previous issue and this current issue	Page number
Year of publication amended from 2019 to 2020	
Issue number amended from 6 to 7	
<p>1.2, 1.7, 1.8, 1.9, 2.2, 2.3, 2.4, 2.5.1, 2.6, 2.7, 3.2.1, 3.6.3, 3.7, 3.7.4, 4.1, 4.2.1, 5, 5.1, 5.2, 5.4.1, 7.7, Appendix 6</p> <p>Minor typographical, language and formatting errors corrected.</p>	<p><b>2, 5, 6-10, 12, 13, 15, 16, 19, 24-28, 36, 40, 42, 44, 46, 48, 50-52, 63-65, 67, 93, 533, 536</b></p>
<p>1.4 Qualification Titles</p> <p>New Level 4 and Level 5 qualification titles added:</p> <ul style="list-style-type: none"> <li>• Pearson BTEC Level 4 Higher National Certificate in Engineering (Semiconductor Technologies)</li> <li>• Pearson BTEC Level 5 Higher National Diploma in Engineering (Semiconductor Technologies)</li> <li>• Pearson BTEC Level 5 Higher National Diploma in Engineering (Embedded Electronic Systems)</li> </ul> <p>Pearson BTEC duplicate text removed from Level 5 qualification titles</p>	<p><b>3</b></p>
<p>1.8 Collaborative development</p> <p>Additional organisations added:</p> <ul style="list-style-type: none"> <li>• Newport Wafer Fab Ltd.</li> <li>• Microchip Technology Inc.</li> <li>• SPTS Technologies Ltd.</li> <li>• IQE PLC</li> </ul> <p>Additional higher education providers added:</p> <ul style="list-style-type: none"> <li>• University of South Wales</li> <li>• Cardiff and Vale College</li> </ul>	<p><b>5 &amp; 6</b></p>
<p>2.3 Aims of the Pearson BTEC Level 4 Higher National Certificate in Engineering</p> <p>Updated section to include new Semiconductor Technologies pathway.</p>	<p><b>9 &amp; 10</b></p>

2.4 Aims of the Pearson BTEC Level 5 Higher National Diploma in Engineering Updated section to include new Semiconductor Technologies pathway and new Embedded Electronic Systems pathway.	<b>11</b>
4.3 Pearson-Set Assignments Corrected as Pearson-Set Units and the narrative is amended to reflect that the scope of Pearson-Set is limited to a set annual theme only (i.e. topics are not set by Pearson) in all Engineering qualifications.	<b>59</b>
6 Assessment 'Pearson-set assignment' is corrected as 'Pearson-set theme'. Related text is revised to reflect the change.	<b>77</b>
6.0.1 Example Assessment Briefs A general website link is replaced by a specific HN Global link.	<b>78</b>
6.2.3 Forms of evidence 'Learning aim(s)' is corrected as 'learning outcomes'.	<b>82</b>
6.5.2 Compensation provisions Compensation provision for both the HNC and HND awards is clarified by revising the wording in the paragraphs as 'if they have attempted the assessment but not achieved a Pass'. This is to confirm what is expected of a student to qualify for compensation in claiming the award.	<b>88</b>
10 Higher Nationals Engineering Units Added new units at Level 4: <ul style="list-style-type: none"> <li>● Statistical Process Control</li> <li>● Telecommunication Principles</li> <li>● Semiconductor Manufacture*</li> <li>● Semiconductor Production Environments*</li> </ul> Added new units at Level 5: <ul style="list-style-type: none"> <li>● Emerging Semiconductor Technologies*</li> <li>● Semiconductor Integrated Electronics*</li> </ul>	<b>82</b> <b>83</b> <b>84</b> <b>85</b> <b>86</b> <b>87</b>
Unit 31 Assignment criteria D4 corrected to D4 Validate the selection of suitable electrical safety devices for a specific industrial application	<b>269</b>

<p>Appendix 2: HNC/HND Engineering Programme Outcomes for Learners</p> <p>Table updated to reflect new units</p>	<b>570</b>
<p>Appendix 3: Pearson BTEC Level 5 Higher National Diploma in Engineering:</p> <ul style="list-style-type: none"> <li>• Mapping of transferable employability and academic study skills</li> <li>• Table updated to reflect new units</li> </ul>	<b>571</b>

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](https://qualifications.pearson.com/en/support/contact-us.html).



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

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

## 1.1 The Student Voice

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

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

## 1.2 Why choose Pearson BTEC Higher Nationals?

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

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

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

## 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 <https://hnglobal.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 Engineering**

Specialist pathways are included within brackets in the qualification title:

- Pearson BTEC Level 4 Higher National Certificate in Engineering (Electrical and Electronic Engineering)
- Pearson BTEC Level 4 Higher National Certificate in Engineering (General Engineering)
- Pearson BTEC Level 4 Higher National Certificate in Engineering (Manufacturing Engineering)
- Pearson BTEC Level 4 Higher National Certificate in Engineering (Mechanical Engineering)
- Pearson BTEC Level 4 Higher National Certificate in Engineering (Operations Engineering)
- Pearson BTEC Level 4 Higher National Certificate in Engineering (Semiconductor Technologies).

### **Pearson BTEC Level 5 Higher National Diploma in Engineering**

Specialist pathways are included within brackets in the qualification title:

- Pearson BTEC Level 5 Higher National Diploma in Engineering (Electrical and Electronic Engineering)
- Pearson BTEC Level 5 Higher National Diploma in Engineering (General Engineering)
- Pearson BTEC Level 5 Higher National Diploma in Engineering (Manufacturing Engineering)
- Pearson BTEC Level 5 Higher National Diploma in Engineering (Mechanical Engineering)

- Pearson BTEC Level 5 Higher National Diploma in Engineering (Operations Engineering)
- Pearson BTEC Level 5 Higher National Diploma in Engineering (Semiconductor Technologies)
- Pearson BTEC Level 5 Higher National Diploma in Engineering (Embedded Electronic Systems).

## 1.5 Qualification codes

Regulated Qualifications Framework (RQF) Qualification number:

- Pearson BTEC Level 4 Higher National Certificate in Engineering: 603/0450/9
- Pearson BTEC Level 5 Higher National Diploma in Engineering: 603/0451/0.

## 1.6 Awarding organisation

Pearson Education Ltd.

## 1.7 Key features

Pearson BTEC Higher National qualifications in Engineering offer:

- A stimulating and challenging programme of study that will be both engaging and memorable for students.
- The essential subject knowledge that students need to progress successfully within or into the world of work or onto further study.
- A simplified structure: students undertake a substantial core of learning, required by all engineers, with limited specialism in the Higher National Certificate, building on this in the Higher National Diploma, with further specialist and optional units linked to their specialist area of study.
- One general and four specialist pathways at Level 4 and 5 so there is something to suit each student's preference for study and future progression plans.
- Refreshed content that is closely aligned with employer, Professional Body and higher education needs.
- Assessments that consider cognitive skills (what students know) along with effective and applied skills (respectively how they behave and what they can do).
- Unit-specific grading and Pearson-set assignments.
- A varied approach to assessment that supports progression to Level 6 and also allows centres to offer assessment relevant to the local economy, thereby accommodating and enhancing different learning styles.



- Quality assurance measures – as outlined in sections 6 and 7 of this Qualification Specification – to ensure that all stakeholders (e.g. Professional Bodies, universities, businesses, colleges and students) can feel confident in the integrity and value of the qualifications.
- A qualification designed to meet the needs and expectations of students aspiring to work in an international setting.

## **Qualification frameworks**

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

## **1.8 Collaborative development**

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

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

- Alstom
- BMW
- Eaton
- GEN 2
- Jaguar Land Rover
- Railtrack
- Siemens
- UAE Military Logistics Support
- Engineering Council
- Royal Aeronautical Society
- Royal Academy of Engineering
- SEMTA
- Society of Operations Engineers

- The Institution of Engineering and Technology
- The Institute of the Motor Industry
- The Welding Institute
- NFEC (National Forum of Engineering Centres).
- Newport Wafer Fab Ltd.
- Microchip Technology Inc.
- SPTS Technologies Ltd.
- IQE Plc.

Higher education providers that have collaborated with us include:

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

## 1.9 Professional Body consultation and approval

Qualifications in engineering within the UK are referenced against the Engineering Council, UK Standard for Professional Engineering Competence (UK-SPEC) which sets standards at Levels 3, 6 and 8.

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

Holders of a Pearson BTEC Higher National in Engineering meet the academic requirements for the Engineering Council Engineering Technician Standard (**EngTech**).

## 2. Programme purpose and objectives

### 2.1 Purpose of the Pearson BTEC Higher Nationals in Engineering

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

### 2.2 Objectives of the Pearson BTEC Higher Nationals in Engineering

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

- To provide students with the core knowledge, skills and techniques that all engineers require, irrespective of future specialism, to achieve high performance in the engineering profession.
- To build a body of specialist knowledge, skills and techniques in order to be successful in a range of careers in engineering at the Technician or Engineer level.
- To develop the skills necessary for fault finding and problem solving in a timely, professional manner, reflecting on their work and contributing to the development of the process and environment they operate within.
- To understand the responsibilities of the engineer within society, and work with integrity, regard for cost, sustainability and the rapid rate of change experienced in world class engineering.
- To provide opportunities for students to enter, or progress in, employment within the engineering 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 provide opportunities for students to make progress towards achieving internationally recognised registration with a Professional Body regulated by the Engineering Council.
- To allow flexibility of study and to meet local or specialist needs.

We aim to meet these objectives by:

- Providing a thorough grounding in engineering principles at Level 4 that leads the student to a range of specialist progression pathways at Level 5, relating to individual professions within the engineering sector.
- Equipping individuals with the essential qualities of an engineer, including integrity, regard for cost and sustainability, as they apply to a range of roles and responsibilities within the 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 or 5.
- Enabling progression to further professional qualifications in specific engineering disciplines by mapping the units studied to the requirements of the Professional Bodies applicable to that discipline.
- Supporting a range of study modes and timeframes for completion of the qualifications.

### **Who is this qualification for?**

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

## **2.3 Aims of the Pearson BTEC Level 4 Higher National Certificate in Engineering**

The Pearson BTEC Level 4 Higher National Certificate in Engineering 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 while preparing the student for more intense subject specialisation at Level 5. Students will gain a wide range of sector knowledge tied to practical skills gained in research, self-study, directed study and workplace activities.

The Pearson BTEC Level 4 Higher National Certificate offers six pathways for students who wish to concentrate on a particular aspect of engineering:

- Electrical and Electronic
- General
- Manufacturing

- Mechanical
- Operations
- Semiconductor Technologies.

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

- Unit 1: Engineering Design
- Unit 2: Engineering Maths
- Unit 3: Engineering Science
- Unit 4: Managing a Professional Engineering Project\*.

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

- For the Electrical and Electronic Engineering pathway, students take the four mandatory core units, one specialist unit and three additional optional units.
- For the General Engineering pathway, students take the four mandatory core units and an additional four optional units.
- For the Manufacturing Engineering pathway, students take the four mandatory core units, two specialist units and an additional two optional units.
- For the Mechanical Engineering pathway, students take the four mandatory core units, two specialist units and an additional two optional units.
- For the Operations Engineering pathway, students take the four mandatory core units and an additional four optional units.
- For the Semiconductor Technologies pathway, students take the four mandatory core units, two specialist units and an additional two optional units.

(See *section 4.2* for a full list of the mandatory core, specialist and optional units for each pathway.)

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

## 2.4 Aims of the Pearson BTEC Level 5 Higher National Diploma in Engineering

The Pearson BTEC Level 5 Higher National Diploma in Engineering offers students seven pathways, designed to support progression into relevant occupational areas or onto degree-level study. These pathways are linked to Professional Body standards (where appropriate) and can provide progression towards professional status or entry to the later stages of an appropriate degree.

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

The Pearson BTEC Level 5 Higher National Diploma offers seven pathways for students who wish to concentrate on a particular aspect of engineering:

- Electrical and Electronic
- General
- Manufacturing
- Mechanical
- Operations
- Semiconductor Technologies
- Embedded Electronic Systems.

At Level 5 students continue to build on the essential skills, knowledge and techniques necessary for all engineers whilst working through a larger number of subject-specific specialist and optional units. The two mandatory core units at Level 5 are:

- Unit 34: Research Project
- Unit 35: Professional Engineering Management\*.  
\*(Unit 35: Professional Engineering Management is also the Pearson-set assignment unit)
- For the Electrical and Electronic Engineering pathway, students take the two mandatory core units, three specialist units and an additional two optional units.
- For the General Engineering pathway, students take the two mandatory core units, two specialist units and an additional three optional units.
- For the Manufacturing Engineering pathway, students take the two mandatory core units, three specialist units and an additional two optional units.

- For the Mechanical Engineering pathway, students take the two mandatory core units, three specialist units and an additional two optional units.
- For the Operations Engineering pathway, students take the two mandatory core units, four specialist units and an additional Optional unit
- For the Semiconductor Technologies pathway, students take the two mandatory core units, two specialist units and an additional three optional units.
- For the Embedded Electronic Systems pathway, students study the Electrical and Electronic Engineering pathway at Level 4 and take the two mandatory core units, two specialist units and an additional three optional units at Level 5.

(See *section 4.2* for a full list of the mandatory core, specialist and optional units for each pathway.)

## **2.5 What could these qualifications lead to?**

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

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

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



### 2.5.1 Progression to university

The Pearson BTEC Level 5 Higher National Diploma is recognised by Higher Education providers as meeting admission requirements to many relevant engineering degree programmes in subject specialisms such as:

- Engineering
- Electronic and Electrical Engineering
- Production and Manufacturing Engineering
- Mechanical Engineering
- Operations Engineering
- Semiconductor Technologies
- Embedded Electronic Systems.

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

#### **University recognition and articulations**

We work with a number of universities around the world to recognise and accept Pearson BTEC Higher National Certificate or Diploma as a qualification for entry onto an undergraduate degree. Many universities now allow advanced entry onto the corresponding second or third year of a degree. Some universities have direct articulations on to the second or third year of a bachelor's degree programme with Pearson BTEC Higher Nationals. Students should be aware that university admission criteria is always subject to change and understand the course entry requirements for subject, year and grade before applying.

For more information on entry requirements, including 2+1 articulations, please visit: <https://degreecoursefinder.pearson.com>

## 2.5.2 Employment

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

Pathway	Typical Job Roles after HNC	Typical Job Roles after HND
Electrical and Electronic Engineering	Electrical Engineering Technician Electronics Engineering Technician	Electrical Engineer Electronic Engineer
Manufacturing Engineering	Manufacturing Systems Technician	Manufacturing Systems Engineer
Mechanical Engineering	Mechanical Engineering Technician	Mechanical Engineer
Operations Engineering	Automotive Engineering Technician	Automotive Engineer
General Engineering	Engineering Maintenance Technician	Maintenance Engineer
Semiconductor Technologies	Process Technician, Equipment Technician, Fabrication Technician, Device & Test Technician, Assembly Technician	Process Engineer, Equipment Engineer, Electronic & Assembly/Test Engineer, Fabrication Engineer
Embedded Electronic Systems	Electronics Engineering Technician	Embedded Electronic Systems Engineer

## 2.6 Use of Maths and English within the curriculum

Those working within the engineering sector cannot just rely on their technical skills and must ensure 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 these qualifications, as part of learning activities and assessments 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 calculus to solve practical problems relating to engineering.

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

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

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

Where employability skills are referred to in this specification, this generally refers to skills in three main categories and also specific commercial and business skills.

- **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.
- **Commercial skills:** sector awareness, budget management/monitoring.
- **Business skills:** awareness of types of companies, company formation, calculating fees, project management.

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

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

- Active research skills
- Effective writing skills
- Analytical skills
- Critical thinking
- Creative problem-solving
- Decision-making
- Team building
- Exam preparation skills
- Digital literacy
- Practical design and build skills
- Experimental and testing techniques
- Competence in assessment methods used in higher education.

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

## 3. Planning your programme

### 3.1 Delivering the Higher National qualifications

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

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

You will need to ensure that your students have access to a full range of information, advice and guidance 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:

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

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

### 3.2.1 English language requirements for Higher Nationals

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.

### 3.2.2 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/>).

### 3.2.3 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.

### 3.2.4 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 Pearson BTEC Higher Nationals. For some units, specific resources are required, this is clearly indicated in the unit descriptors.

### 3.2.5 HN Global support

HN Global (<https://hnglobal.highernationals.com/>) is an online resource that supports centre planning and delivery of Pearson BTEC Higher Nationals by providing appropriate teaching and learning resources. For further information see *sections 5 and 6* of this Programme Specification.

### 3.2.6 Modes of delivery

Subject to approval by Pearson, centres are free to deliver Pearson 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 (partially).

### 3.2.7 Recommendations for employer engagement

Pearson 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.

### 3.2.8 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.



### 3.2.9 Student employability

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

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

### 3.3 Access to study

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

Our policy regarding access to our qualifications is that:

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

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

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

### 3.4 Student registration and entry

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

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

### 3.5 Access to assessment

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

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

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

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

### 3.6 Administrative arrangements for internal assessment

#### 3.6.1 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.

### 3.6.2 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/>).

### 3.6.3 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 the 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.

### 3.6.4 Appeals against assessment

Centres 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, centres 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 a centre is located in England or Wales and students are still dissatisfied with the final outcome of their appeal they can make a further appeal to the office of the Independent Adjudicator (OIA) by emailing: [enquiries@oiahe.org.uk](mailto: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](mailto: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 or centre staff 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.

#### **3.7.1 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.

#### **3.7.2 Student malpractice**

Student malpractice refers to any act by a student that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

Heads of Centres are required to report incidents of any suspected student malpractice that occur during assessments. Student malpractice in examinations **must** be reported to Pearson using a *JCQ Form M1* (available at [www.jcq.org.uk/exams-office/malpractice](http://www.jcq.org.uk/exams-office/malpractice)). The form should be emailed to [candidatemalpractice@pearson.com](mailto:candidatemalpractice@pearson.com). Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions 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.

Failure to report malpractice constitutes staff or centre malpractice.

### 3.7.3 Staff and centre malpractice

Staff and centre malpractice includes both deliberate malpractice and maladministration of our qualifications. As with candidate malpractice, staff and centre malpractice is any act that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

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. All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ Form M2(a)* (available at [www.jcq.org.uk/exams-office/malpractice](http://www.jcq.org.uk/exams-office/malpractice)). The form, supporting documentation and as much information as possible should be emailed to [pqsmalpractice@pearson.com](mailto:pqsmalpractice@pearson.com)

Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More-detailed guidance on malpractice can be found in the latest version of the document *Suspected Malpractice in Examinations and Assessments*, available at [www.jcq.org.uk/exams-office/malpractice](http://www.jcq.org.uk/exams-office/malpractice).

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](http://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.

### 3.7.4 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 a centre's quality procedures, we may impose sanctions such as:

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

The 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](mailto:pqsmalpractice@pearson.com)), and they will inform you of the next steps .

## 4. Programme structure

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

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

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

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

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

Pearson BTEC Higher Nationals consist of core units, specialist units and optional units:

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

All units are usually 15 credits in value, or a multiple thereof. These units have been designed from a learning time perspective, and are expressed in terms of **Total Qualification Time (TQT)**. TQT is an estimate of the total amount of time that could reasonably be expected for a student to 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**

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

Examples of activities which can contribute to TQT include:

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

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

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

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

Some examples of activities which can contribute to 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.

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

Each pathway, except General Engineering, also has a number of specialist units which are selected and recommended to provide an appropriate amount of subject specific content for that pathway title and level. In the case of the Operations pathway, specialist units may only be selected from the designated specialist unit list.

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

### 4.2.1 Pearson BTEC Level 4 Higher National Certificate in Engineering

Qualification credit value: a minimum of 120 credits. This is made up of eight units, each with a value of 15 credits.

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

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

<b>Pearson BTEC Level 4 Higher National Certificate in Engineering (Electrical and Electronic Engineering) (120 credits)</b>		<b>Unit credit</b>	<b>Level</b>
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist <i>Mandatory</i>	<b>19 Electrical and Electronic Principles*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

Note: The Electrical and Electronic Engineering pathway at Level 4 is the prerequisite pathway for students who wish to progress to study the Embedded Electronic Systems pathway at Level 5.

Pearson BTEC Level 4 Higher National Certificate in Engineering (General Engineering) (120 credits)		Unit credit	Level
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

Pearson BTEC Level 4 Higher National Certificate in Engineering (Manufacturing Engineering) (120 credits)		Unit credit	Level
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist unit <i>Mandatory</i>	<b>14 Production Engineering for Manufacture*</b>	15	4
Specialist unit <i>Mandatory</i>	<b>17 Quality and Process Improvement*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

\*specialist unit also available as an optional unit.

Pearson BTEC Level 4 Higher National Certificate in Engineering (Mechanical Engineering) (120 credits)		Unit credit	Level
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist unit <i>Mandatory</i>	<b>8 Mechanical Principles*</b>	15	4
Specialist unit <i>Mandatory</i>	<b>13 Fundamentals of Thermodynamics and Heat Engines*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b> <i>Note: If the student has no prior practical experience then it is recommended that Unit 10 Mechanical Workshop Practices is the selected optional unit.</i>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

\*specialist unit also available as an optional unit

Pearson BTEC Level 4 Higher National Certificate in Engineering (Operations Engineering) (120 credits)		Unit credit	Level
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Optional unit	<b>Plus one optional unit from Optional Unit Bank Group B (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from Optional Unit Bank Group B (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from Optional Unit Bank Group B (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Pearson BTEC Level 4 Higher National Certificate in Engineering (Semiconductor Technologies) (120 credits)</b>		<b>Unit credit</b>	<b>Level</b>
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist <i>Mandatory</i>	<b>84 Semiconductor Manufacture*</b>	15	4
Specialist <i>Mandatory</i>	<b>85 Semiconductor Production Environments*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

\*specialist unit also available as an optional unit

<b>Higher National Certificate Optional Units</b>		<b>Unit credit</b>	<b>Level</b>
<b>Optional units Level 4:</b>			
<b>Optional Unit Bank Group B: Operations Engineering</b>			
Optional	<b>29 Electro, Pneumatic and Hydraulic Systems</b>	15	4
Optional	<b>30 Operations and Plant Management</b>	15	4
Optional	<b>31 Electrical Systems and Fault Finding</b>	15	4
Optional	<b>32 CAD for Maintenance Engineers</b>	15	4
<b>General Optional Bank Level 4: All other pathways</b>			
Optional	<b>5 Renewable Energy</b>	15	4
Optional	<b>6 Mechatronics</b>	15	4
Optional	<b>7 Machining and Processing of Engineering Materials</b>	15	4
Optional	<b>8 Mechanical Principles*</b>	15	4
Optional	<b>9 Materials, Properties and Testing</b>	15	4
Optional	<b>10 Mechanical Workshop Practices</b>	15	4
Optional	<b>11 Fluid Mechanics</b>	15	4
Optional	<b>12 Engineering Management</b>	15	4
Optional	<b>13 Fundamentals of Thermodynamics and Heat Engines*</b>	15	4
Optional	<b>14 Production Engineering for Manufacture*</b>	15	4
Optional	<b>15 Automation, Robotics and Programmable Logic Controllers (PLCs)</b>	15	4
Optional	<b>16 Instrumentation and Control Systems</b>	15	4
Optional	<b>17 Quality and Process Improvement*</b>	15	4
Optional	<b>18 Maintenance Engineering</b>	15	4
Optional	<b>19 Electrical and Electronic Principles*</b>	15	4
Optional	<b>20 Digital Principles</b>	15	4
Optional	<b>21 Electrical Machines</b>	15	4
Optional	<b>22 Electronic Circuits and Devices*</b>	15	4
Optional	<b>23 Computer Aided Design and Manufacture (CAD/CAM)</b>	15	4



Optional	<b>29 Electro, Pneumatic and Hydraulic Systems</b>	15	4
Optional	<b>30 Operations and Plant Management</b>	15	4
Optional	<b>31 Electrical Systems and Fault Finding</b>	15	4
Optional	<b>32 CAD for Maintenance Engineers</b>	15	4
Optional	<b>73 Materials Engineering with Polymers</b>	15	4
Optional	<b>74 Polymer Manufacturing Processes</b>	15	4
Optional	<b>75 Industry 4.0</b>	15	4
Optional	<b>76 Introduction to Professional Engineering Management</b>	15	4
Optional	<b>77 Industrial Robots</b>	15	4
Optional	<b>78 Programmable Logic Controllers</b>	15	4
Optional	<b>79 Computer Aided Design (CAD) for Engineering</b>	15	4
Optional	<b>80 Welding Technologies</b>	15	4
Optional	<b>81 Welding Inspection</b>	15	4
Optional	<b>82 Statistical Process Control</b>	15	4
Optional	<b>83 Telecommunication Principles</b>	15	4
Optional	<b>84 Semiconductor Manufacture*</b>	15	4
Optional	<b>85 Semiconductor Production Environments*</b>	15	4

\*optional unit also available as a specialist unit

## 4.2.2 Pearson BTEC Level 5 Higher National Diploma in Engineering

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

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

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

Pearson BTEC Level 5 Higher National Diploma in Engineering (Electrical and Electronic Engineering) (240 Credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist unit <i>Mandatory</i>	<b>19 Electrical and Electronic Principles</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>39 Further Mathematics*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>44 Industrial Power, Electronics and Storage*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>45 Industrial Systems*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5

\*specialist units also available as optional units

Pearson BTEC Pearson BTEC Level 5 Higher National Diploma in Engineering (General Engineering) (240 Credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>39 Further Mathematics*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>49 Lean Manufacturing*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5

\*specialist units also available as optional units

Pearson BTEC Pearson BTEC Level 5 Higher National Diploma in Engineering (Manufacturing Engineering) (240 Credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist unit <i>Mandatory</i>	<b>14 Production Engineering for Manufacture</b>	15	4
Specialist unit <i>Mandatory</i>	<b>17 Quality and Process Improvement*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>48 Manufacturing Systems Engineering*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>49 Lean Manufacturing*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>50 Advanced Manufacturing Technology*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5

\*specialist units also available as optional units



Pearson BTEC Pearson BTEC Level 5 Higher National Diploma in Engineering (Mechanical Engineering) (240 Credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist unit <i>Mandatory</i>	<b>8 Mechanical Principles</b>	15	4
Specialist unit <i>Mandatory</i>	<b>13 Fundamentals of Thermodynamics and Heat Engines</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b> <i>Note: if the student has no prior practical experience then it is recommended that Unit 10: Mechanical Workshop Practices is the selected optional unit.</i>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>36 Advanced Mechanical Principles</b>	15	5
Specialist unit <i>Mandatory</i>	<b>37 Virtual Engineering*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>39 Further Mathematics*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5

\*specialist units also available as optional units

Pearson BTEC Pearson BTEC Level 5 Higher National Diploma in Engineering (Operations Engineering) (240 Credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Optional unit	<b>Plus one optional unit from Optional Unit Bank Group B (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from Optional Unit Bank Group B (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from Optional Unit Bank Group B (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>39 Further Mathematics*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>62 Heating, Ventilation, Air Conditioning (HVAC)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>63 Industrial Services</b>	15	5
Specialist unit <i>Mandatory</i>	<b>64 Thermofluids*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 optional bank (see below)</b>	15	5

\*specialist unit also available as optional unit

Pearson BTEC Level 5 Higher National Diploma in Engineering (Semiconductor Technologies) (240 credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist <i>Mandatory</i>	<b>84 Semiconductor Manufacture*</b>	15	4
Specialist <i>Mandatory</i>	<b>85 Semiconductor Production Environments*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>86 Emerging Semiconductor Technologies*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>87 Semiconductor Integrated Electronics*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5

\*specialist units also available as optional units

Pearson BTEC Level 5 Higher National Diploma in Engineering (Embedded Electronic Systems) (240 credits)		Unit credit	Level
<b>Level 4 units</b>			
Core unit <i>Mandatory</i>	<b>1 Engineering Design</b>	15	4
Core unit <i>Mandatory</i>	<b>2 Engineering Maths</b>	15	4
Core unit <i>Mandatory</i>	<b>3 Engineering Science</b>	15	4
Core unit <i>Mandatory</i>	<b>4 Managing a Professional Engineering Project (Pearson-set)</b>	15	4
Specialist <i>Mandatory</i>	<b>19 Electrical and Electronic Principles*</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4
Optional unit	<b>Plus one optional unit from General Optional Bank Level 4 (see below)</b>	15	4

\*specialist unit also available as an optional unit

<b>Level 5 units</b>			
Core unit <i>Mandatory</i>	<b>34 Research Project</b>	30	5
Core unit <i>Mandatory</i>	<b>35 Professional Engineering Management (Pearson-set)</b>	15	5
Specialist unit <i>Mandatory</i>	<b>39 Further Mathematics*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>40 Commercial Programming Software*</b>	15	5
Specialist unit <i>Mandatory</i>	<b>4 Embedded Systems*</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5
Optional unit	<b>Plus one optional unit from Level 5 Optional Bank (see below)</b>	15	5

\*specialist unit also available as an optional unit

Note: The prerequisite pathway for students studying the Embedded Electronic Systems pathway at Level 5 is the Electrical and Electronic Engineering pathway at Level 4.



<b>Higher National Diploma Optional Units</b>		<b>Unit credit</b>	<b>Level</b>
<b>Optional Unit Bank Group B: Operations Engineering</b>			
Optional	<b>29 Electro, Pneumatic and Hydraulic Systems</b>	15	4
Optional	<b>30 Operations and Plant Management</b>	15	4
Optional	<b>31 Electrical Systems and Fault Finding</b>	15	4
Optional	<b>32 CAD for Maintenance Engineers</b>	15	4
<b>General Optional Bank Level 4: All other pathways</b>			
Optional	<b>5 Renewable Energy</b>	15	4
Optional	<b>6 Mechatronics</b>	15	4
Optional	<b>7 Machining and Processing of Engineering Materials</b>	15	4
Optional	<b>8 Mechanical Principles*</b>	15	4
Optional	<b>9 Materials, Properties and Testing</b>	15	4
Optional	<b>10 Mechanical Workshop Practices</b>	15	4
Optional	<b>11 Fluid Mechanics</b>	15	4
Optional	<b>12 Engineering Management</b>	15	4
Optional	<b>13 Fundamentals of Thermodynamics and Heat Engines*</b>	15	4
Optional	<b>14 Production Engineering for Manufacture*</b>	15	4
Optional	<b>15 Automation, Robotics and Programmable Logic Controllers (PLCs)</b>	15	4
Optional	<b>16 Instrumentation and Control Systems</b>	15	4
Optional	<b>17 Quality and Process Improvement*</b>	15	4

Optional	<b>18 Maintenance Engineering</b>	15	4
Optional	<b>19 Electrical and Electronic Principles*</b>	15	4
Optional	<b>20 Digital Principles</b>	15	4
Optional	<b>21 Electrical Machines</b>	15	4
Optional	<b>22 Electronic Circuits and Devices*</b>	15	4
Optional	<b>23 Computer Aided Design and Manufacture (CAD/CAM)</b>	15	4
Optional	<b>29 Electro, Pneumatic and Hydraulic Systems</b>	15	4
Optional	<b>30 Operations and Plant Management</b>	15	4
Optional	<b>31 Electrical Systems and Fault Finding</b>	15	4
Optional	<b>32 CAD for Maintenance Engineers</b>	15	4
Optional	<b>73 Materials Engineering with Polymers</b>	15	4
Optional	<b>74 Polymer Manufacturing Processes</b>	15	4
Optional	<b>75 Industry 4.0</b>	15	4
Optional	<b>76 Introduction to Professional Engineering Management</b>	15	4
Optional	<b>77 Industrial Robots</b>	15	4
Optional	<b>78 Programmable Logic Controllers</b>	15	4
Optional	<b>79 Computer Aided Design (CAD) for Engineering</b>	15	4
Optional	<b>80 Welding Technologies</b>	15	4
Optional	<b>81 Welding Inspection</b>	15	4
Optional	<b>82 Statistical Process Control</b>	15	4

Optional	<b>83 Telecommunication Principles</b>	15	4
Optional	<b>84 Semiconductor Manufacture*</b>	15	4
Optional	<b>85 Semiconductor Production Environment*</b>	15	4
<b>Level 5 Optional Bank</b>			
Optional	<b>36 Advanced Mechanical Principles</b>	15	5
Optional	<b>37 Virtual Engineering*</b>	15	5
Optional	<b>38 Further Thermodynamics</b>	15	5
Optional	<b>39 Further Mathematics*</b>	15	5
Optional	<b>40 Commercial Programming Software</b>	15	5
Optional	<b>41 Distributed Control Systems</b>	15	5
Optional	<b>42 Further PLCs</b>	15	5
Optional	<b>43 Further Electrical Machines and Drives</b>	15	5
Optional	<b>44 Industrial Power, Electronics and Storage*</b>	15	5
Optional	<b>45 Industrial Systems*</b>	15	5
Optional	<b>46 Embedded Systems</b>	15	5
Optional	<b>47 Analogue Electronic Systems</b>	15	5
Optional	<b>48 Manufacturing Systems Engineering*</b>	15	5
Optional	<b>49 Lean Manufacturing*</b>	15	5
Optional	<b>50 Advanced Manufacturing Technology*</b>	15	5
Optional	<b>51 Sustainability</b>	15	5
Optional	<b>52 Further Electrical, Electronic and Digital Principles</b>	15	5

Optional	<b>53 Utilisation of Electrical Power</b>	15	5
Optional	<b>54 Further Control Systems Engineering</b>	15	5
Optional	<b>62 Heating, Ventilation, Air Conditioning (HVAC)*</b>	15	5
Optional	<b>63 Industrial Services*</b>	15	5
Optional	<b>64 Thermofluids*</b>	15	5
Optional	<b>86 Emerging Semiconductor Technologies*</b>	15	5
Optional	<b>87 Semiconductor Integrated Electronics*</b>	15	5

\*Optional units are also denoted as a specialist unit in particular pathways

### 4.2.3 Meeting local needs (MLN)

Centres should note that Pearson BTEC Higher National qualifications have been developed in consultation with centres, employers and relevant professional organisations. The units were designed to meet the skill needs of the sector and thereby allow coverage of the full range of employment within the sector. Centres should make maximum use of the choices available to them within the specialist pathways 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 to use units from other RQF Pearson BTEC Higher National qualifications, through the MLN process (refer to *Commissioned qualification design and validation service* of our website

<http://qualifications.pearson.com> or get in touch your Pearson regional contact for application details. Centres will need to justify the rationale for importing units from other RQF Pearson BTEC Higher National specifications. **Meeting local need applications must be made in advance of delivery and before 31 January in the year of student registration.**

The flexibility to import standard units from other RQF Pearson BTEC Higher National specifications is **limited to a maximum of 30 credits in a BTEC HNC qualification and a maximum of 60 credits in a BTEC HND qualification (30 credits at Level 4 and 30 credits at Level 5)**. This is an overall maximum of units that can be imported. MLN units cannot be used at the expense of the mandatory units in any qualification nor can the qualification's rules of combination, as detailed in the specification, be compromised. It is the responsibility of the centre requesting the MLN to ensure that approved units are used only in eligible combinations.

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

Qualification	Pathway	Import at Level 4	Import at Level 5
HNC Engineering	<b>Electrical and Electronic Engineering</b>	30	-
	<b>General Engineering</b>	30	-
	<b>Manufacturing Engineering</b>	30	-
	<b>Mechanical Engineering</b>	30	-
	<b>Operations Engineering</b>	30	-
	<b>Semiconductor Technologies</b>	30	-
HND Engineering	<b>Electrical and Electronic Engineering</b>	30	30
	<b>General Engineering</b>	30	30
	<b>Manufacturing Engineering</b>	30	30
	<b>Mechanical Engineering</b>	30	30
	<b>Operations Engineering</b>	30	30
	<b>Semiconductor Technologies</b>	30	30
	<b>Embedded Electronic Systems</b>	30	30

#### 4.2.4 Pearson BTEC Higher National Commissioned Development

Where MLN does not provide enough flexibility in terms of qualification structure, centres can request design and development of units by Pearson to meet their specific needs. This is offered by the following types of developments; full commission or partial commission.

We would be pleased to discuss your ideas for a Pearson BTEC Higher National Commissioned Development. For more information please refer to the *Commissioned qualification design and validation service* on our website <http://qualifications.pearson.com>

Once the centre is ready to proceed with a commissioned development, an application must be made, which provides a clear rationale for the development request. Pearson will review the application and may confirm or deny the request. The commissioned unit(s) will be authored by Pearson, in full consultation within the commissioning centre. Applications must be made one year in advance of the first year of commissioned unit(s) delivery.

### 4.3 Pearson-Set Units

There are Pearson-set units, as part of Core units. 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, tutors will select a Topic to further define the students' approach to the Theme and assignment. At Level 5, it is expected that students will define their own Topic, in negotiation with tutors, based on the Pearson-set Theme.

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

The aim of the Pearson-set units 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 The unit descriptor

The Unit Descriptor is how we define 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.

We have described each part of the unit, as below. You may refer to any of the Unit Descriptors in *Section 10* of this programme specification.

<b>Unit Title</b>	A broad statement of what the unit will cover.
<b>Unit Code</b>	The Ofqual unit designation
<b>Unit Type</b>	There are three unit types: core (mandatory to all pathways); specialist (mandatory to specific pathways); and optional (available to most pathways)
<b>Unit level</b>	All Pearson BTEC Higher National units are at Level 4 or Level 5
<b>Credit value</b>	The credit value is related to total qualification time (TQT) and unit learning hours (ULH), and is easy to calculate. 1 credit is equal to 10 ULH, so 15 credits are equal to 150 ULH. To complete a Higher National Certificate or Diploma students are expected to achieve the appropriate number of credits
<b>Introduction</b>	Some general notes on the unit, setting the scene, stating the purpose, outlining the topics and skills gained on completion of the unit
<b>Learning Outcomes</b>	The Learning Outcomes are explicit statements that clearly express what students will be able to do after the completion of the unit. There are, typically, four Learning Outcomes for each unit.
<b>Essential Content</b>	This section covers the content that students can expect to study as they work towards achieving their Learning Outcomes.



**Learning Outcomes and Assessment Criteria**

Each unit sets out the 'Pass', 'Merit' and 'Distinction' criteria for that unit. When assignments are graded, a 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 students work.

**Recommended Resources**

Lists the resources appropriate to support the study of this unit. This includes books, journals and online material to support learning. The programme tutor may suggest alternatives and additions, usually with a local application or relevance.

## Web resources – referencing:

Some units have web resources 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 web 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, which may be one of the following –
  - research
  - general reference
  - tutorials
  - training
  - e-books
  - report
  - wiki
  - article
  - datasets
  - development tool
  - discussion forum.

## Web

- |  |  |
|--|--|
| [1] <a href="http://sdfs.db.aist.go.jp">sdfs.db.aist.go.jp</a> | [2] National Institute for Advanced Industrial Science and Technology (AIST) |
|  | [3] Spectral Database for Organic Compounds, SDBS                            |
|  | [4] (General reference)  |
| [1] <a href="http://rsc.org">rsc.org</a>                       | [2] Royal Society of Chemistry   |
|  | [3] Learn Chemistry  |
|  | [4] (General reference)  |

## 4.5 Professional Body collaboration

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

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

## 5. Teaching and learning

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

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

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

### 5.1 Delivering quality and depth

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

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

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

Centres are expected to provide a broadly similar experience for students to that 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 mode of delivery or pathway on which a student is enrolled 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:

- programme review overview
- preparing for lessons
- effective engagement in lectures, tutorials and practicals
- making the most of their tutor time and support
- assessment 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](http://www.highernationals.com). HN Global provides a wealth of support to ensure that tutors and students have the best possible experience during their course.

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

## 5.2 Engaging with employers

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

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

- field trips to local engineering facilities
- inviting members of the local engineering community to present guest lectures
- using practising engineers to judge the quality of assessed presentations
- involving students in public events such as the Shell Eco-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, as do all Level 5 units. However, this does not mean that units can, or should, be delivered in any order. It is strongly advised that Level 4 units are delivered, and achieved by students before progression to Level 5. However, students are able to progress to Level 5 with a minimum of 90 credits at Level 4.

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

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



### 5.4.2 Condensed, expanded or mixed 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:

Weeks 1 to 6	Week 7	Weeks 8 to 13	Week 14
Unit 1	Assessment	Unit 3	Assessment
Unit 2		Unit 4	

#### Expanded version:

Weeks 1 to 12	Weeks 13 and 14
Unit 1	Assessment
Unit 2	
Unit 3	
Unit 4	

**Mixed version:**

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
<b>Unit 1</b>													<b>Assessment</b>
<b>Unit 2</b>					<b>Assessment</b>	<b>Unit 3</b>							
<b>Unit 4</b>													

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.

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

#### **5.4.4 Assessment considerations**

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

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

#### **5.4.5 Formative assessment**

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

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

#### **5.4.6 Summative assessment**

Summative assessment is where students are provided with the grades contributing towards the overall unit grade. For summative assessment to be effective it should also give students additional formative feedback to support 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

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

- For the HNC, one core, 15-credit, unit at Level 4 will be assessed by a mandatory Pearson-set theme targeted at particular skills.
- For the HND, two core units – one core, 15-credit, unit at Level 4 and one core, 15-credit unit at Level 5 – will be assessed by a mandatory Pearson-set theme targeted at particular knowledge and skills.

All other units are assessed by centre-devised internal assignments.

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

**Standardisation of student work** – Assessing the quality of student work, that it is meeting the level and the requirements of the unit across all centres, that grade decisions and assessor feedback are justified, and that internal verification and moderation processes are picking up any discrepancies and issues.

**Sharing of good practice** – We will share good practice in relation to themes such as innovative approaches to delivery, the use of digital literacy, enhancement of student employability skills and employer engagement. **These themes will align to those for QAA Higher Education Reviews.**

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

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.

### 6.0.1 Example Assessment Briefs

A selection of units have supporting Example Assessment Briefs that are available to download from the course delivery materials section on our website (<https://hnglobal.highernationals.com/subjects>). The Example Assessment Briefs are there to give you an example of what the assessment will look like in terms of the feel and level of demand of the assessment.

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

## 6.1 Principles of internal assessment

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

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

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

### 6.1.1 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 a hand-out 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.

### 6.1.2 Assessment decisions through applying unit-based criteria

Assessment decisions for Pearson 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 career-related attributes appropriate to the purpose of the qualifications.

The assessment criteria for a unit are hierarchical and holistic. For example, if an M criterion requires the student to show 'analysis' and the related P criterion requires the student to 'explain', then to satisfy the M 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 1* 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 outcomes, 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), and 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.

### 6.1.3 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 EE. 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. Placement assessments must be carried out by appropriately qualified assessors.
- Your **External Examiner** (EE) will sample student work across assessors. Your EE will also want to see evidence of internal verification of assignments and assessed decisions.

#### 6.1.4 Effective organisation

Internal assessment needs to be well organised so that 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.

#### 6.1.5 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 they should use and reference source materials, including what would constitute plagiarism.

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

## **6.2 Setting effective assignments**

### **6.2.1 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 EABs 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.

### 6.2.2 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.

### 6.2.3 Forms of evidence

Pearson 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 outcomes 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

### 6.3.1 Authenticity of student work

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

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

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

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

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

### 6.3.2 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 1* of this document
- examples of verified assessed work
- your Programme Leader and assessment team's collective experience.

### 6.3.3 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's policies (see also *Section 3.6*).



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; 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.

#### 6.3.4 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 can suggest how to improve in the future.

#### 6.3.5 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.

### 6.3.6 Repeat Units

In cases of students who, for the first assessment opportunity and resubmission opportunity, still fail to achieve a Pass for that unit specification:

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

### 6.3.7 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 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 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 should have an assessment plan. 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 IV for each assignment, and the date by which the assignment needs to be verified
- setting an approach to sampling assessor decisions through 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

### 6.5.1 Conditions for the award

#### Conditions for the award of the HND

To achieve a Pearson BTEC Level 5 Higher National Diploma qualification a student must have:

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

#### Conditions for the award of the HNC

To achieve a Pearson BTEC Level 4 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.

### 6.5.2 Compensation provisions

#### Compensation provisions for the HND

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

#### Compensation provisions for the HNC

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

### 6.5.3 Calculation of the overall qualification grade

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

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

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

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

#### Points per credit

Grade	Points
Pass	4
Merit	6
Distinction	8

#### Point boundaries

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

## 6.5.4 Modelled student outcomes

### Pearson BTEC Level 4 Higher National Certificate

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

### Pearson BTEC Level 5 Higher National Diploma

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

## 7. Quality assurance

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

The quality assurance process for centres offering Pearson BTEC Higher National programmes comprise 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 EEs. 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 and Level 5 of the AA QAA FHEQ are subject to an independent assessment review by a Pearson appointed EE. 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 (<https://qualifications.pearson.com/en/support/Services/assignment-checking-service.html>). 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 Pearson 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. Higher Nationals Engineering Units

# Unit 1: Engineering Design

<b>Unit code</b>	<b>K/615/1475</b>
<b>Unit type</b>	<b>Core</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## 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
<b>LO1</b> Plan a design solution and prepare an engineering design specification in response to a stakeholder's design brief and requirements		<b>D1</b> Compare and contrast the completed design specification against the relevant industry standard specification
<p><b>P1</b> Produce a design specification from a given design brief</p> <p><b>P2</b> Explain the influence of the stakeholder's design brief and requirements in the preparation of the design specification</p> <p><b>P3</b> Produce a design project schedule with a graphical illustration of the planned activities</p>	<p><b>M1</b> Evaluate potential planning techniques, presenting a case for the method chosen</p> <p><b>M2</b> Demonstrate critical path analysis techniques in design project scheduling/planning and explain its use</p>	
<b>LO2</b> Formulate possible technical solutions to address the student-prepared design specification		<b>D2</b> Evaluate potential technical solutions, presenting a case for the final choice of solution
<p><b>P4</b> Explore industry standard evaluation and analytical tools in formulating possible technical solutions</p> <p><b>P5</b> Use appropriate design techniques to produce a possible design solution</p>	<b>M3</b> Apply the principles of modelling, simulation and/or prototyping, using appropriate software, to develop an appropriate design solution	

Pass	Merit	Distinction
<b>L03</b> Prepare an industry-standard engineering technical design report		<b>D3</b> Evaluate the effectiveness of the industry standard engineering technical design report for producing a fully compliant finished product
<b>P6</b> Prepare an industry-standard engineering technical design report  <b>P7</b> Explain the role of design specifications and standards in the technical design report	<b>M4</b> Assess any compliance, safety and risk management issues specific to the technical design report	
<b>L04</b> Present to an audience a design solution based on the design report and evaluate the solution/presentation		<b>D4</b> Justify potential improvements to the design solution and/or presentation based on reflection and/or feedback
<b>P8</b> Present the recommended design solution to the identified audience  <b>P9</b> Explain possible communication strategies and presentation methods that could be used to inform the stakeholders of the recommended solution	<b>M5</b> 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](http://www.epsrc.ac.uk)                      Engineering and Physical Sciences Research Council  
(General Reference)

[www.imeche.org](http://www.imeche.org)                      Institution of Mechanical Engineers  
(General Reference)

### Links

This unit links to the following related units:

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

*Unit 34: Research Project*

## Unit 2: Engineering Maths

<b>Unit code</b>	<b>M/615/1476</b>
<b>Unit type</b>	<b>Core</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

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

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

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

### Learning Outcomes

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

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

## Essential Content

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

*Mathematical concepts:*

Dimensional analysis

Arithmetic and geometric progressions

*Functions:*

Exponential, logarithmic, trigonometric and hyperbolic functions

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

*Summary of data:*

Mean and standard deviation of grouped data

Pearson's correlation coefficient

Linear regression

Charts, graphs and tables to present data

*Probability theory:*

Binomial and normal distribution

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

*Sinusoidal waves:*

Sine waves and their applications

Trigonometric and hyperbolic identities

*Vector functions:*

Vector notation and properties

Representing quantities in vector form

Vectors in three dimensions



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

### *Differential calculus:*

Definitions and concepts

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

Differentiation of functions

Differentiation of functions including:

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

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

### *Integral calculus:*

Definite and indefinite integration

Integrating to determine area

Integration of functions including:

- common/standard functions
- using substitution
- by parts

Exponential growth and decay

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

### *Engineering problems involving calculus:*

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

## Learning Outcomes and Assessment Criteria

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

Pass	Merit	Distinction
<b>L03</b> Use analytical and computational methods for solving problems by relating sinusoidal wave and vector functions to their respective engineering application		<b>D2</b> Model the combination of sine waves graphically and analyse the variation in results between graphical and analytical methods
<b>P6</b> Solve engineering problems relating to sinusoidal functions <b>P7</b> Represent engineering quantities in vector form, and use appropriate methodology to determine engineering parameters	<b>M3</b> Use compound angle identities to combine individual sine waves into a single wave	
<b>L04</b> Examine how differential and integral calculus can be used to solve engineering problems		<b>D3</b> Analyse maxima and minima of increasing and decreasing functions using higher order derivatives
<b>P8</b> Determine rates of change for algebraic, logarithmic and trigonometric functions <b>P9</b> Use integral calculus to solve practical problems relating to engineering	<b>M4</b> Formulate predictions of exponential growth and decay models using integration methods	

## Recommended Resources

### Textbooks

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

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

### Websites

<http://www.mathcentre.ac.uk/> Maths Centre  
(Tutorials)

<http://www.mathstutor.ac.uk/> Maths Tutor  
(Tutorials)

### Links

This unit links to the following related units:

*Unit 39: Further Mathematics*

## Unit 3: Engineering Science

<b>Unit code</b>	<b>T/615/1477</b>
<b>Unit type</b>	<b>Core</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### 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

Pass	Merit	Distinction
<b>L01</b> Examine scientific data using both quantitative and qualitative methods		<b>D1</b> Analyse scientific data using both quantitative and qualitative methods
<p><b>P1</b> Describe SI units and prefix notation</p> <p><b>P2</b> Examine quantitative and qualitative data with appropriate graphical representations</p>	<b>M1</b> Explain how the application of scientific method impacts upon different test procedures	
<b>L02</b> Determine parameters within mechanical engineering systems		<b>D2</b> Compare how changes in the thermal efficiency of a given system can affect its performance.
<p><b>P3</b> Determine the support reactions of a beam carrying a combination of a concentrated load and a uniformly distributed load</p> <p><b>P4</b> Use Archimedes' principle in contextual engineering applications</p> <p><b>P5</b> Determine the effects of heat transfer on the dimensions of given materials</p>	<b>M2</b> Determine unknown forces by applying d'Alembert's principle to a free body diagram	



Pass	Merit	Distinction
<p><b>L03</b> Explore the characteristics and properties of engineering materials</p>		<p><b>D3</b> Compare and contrast theoretical material properties of metals and non-metals with practical test data</p>
<p><b>P6</b> Describe the structural properties of metals and non-metals with reference to their material properties</p> <p><b>P7</b> Explain the types of degradation found in metals and non-metals</p>	<p><b>M3</b> Review elastic and electromagnetic hysteresis in different materials</p>	
<p><b>L04</b> Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties</p>		<p><b>D4</b> Evaluate different techniques used to solve problems on a combined series-parallel RLC circuit using A.C. theory.</p>
<p><b>P8</b> Calculate currents and voltages in D.C. circuits using circuit theorems</p> <p><b>P9</b> Describe how complex waveforms are produced from combining two or more sinusoidal waveforms.</p> <p><b>P10</b> Solve problems on series RLC circuits with A.C. theory.</p>	<p><b>M4</b> Explain the principles and applications of electromagnetic induction</p>	

## Recommended Resources

### Textbooks

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

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

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

### Journals

*International Journal of Engineering Science*.

*International Journal of Engineering Science and Innovative Technology*.

### Websites

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

### Links

This unit links to the following related units:

*Unit 9: Materials, Properties and Testing*

*Unit 3: Engineering Science*

# Unit 4: Managing a Professional Engineering Project

<b>Unit code</b>	<b>A/615/1478</b>
<b>Unit type</b>	<b>Core</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

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

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

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

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

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

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

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

## **Learning Outcomes**

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

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

### Journals

Journal of Engineering Design.

### Links

This unit links to the following related units:

*Unit 34: Research Project*

*Unit 35: Professional Engineering Management*

## Unit 5:

## Renewable Energy

<b>Unit code</b>	<b>F/615/1479</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

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

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

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

### Learning Outcomes

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

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

## Essential Content

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

*Alternative energy sources, their respective merits and drawbacks:*

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

Waste as energy

storage technologies

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

*Energy demand and security of supply:*

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

Factors affecting changes in energy consumption and demand

Future demand planning based on trends and needs analysis

Risk analysis for energy supplies for UK and local areas

Energy capacity margins analysis related to changes in demand

Alternatives for locally used energy sources

*Energy reduction and efficiency approaches:*

Energy systems available for a given location

Energy legislation and standards

Energy saving and reduction schemes, energy saving technologies available

Energy efficiency approaches for domestic energy use

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

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

*Financial and environmental implications:*

Cost-benefit analysis

Socio-economic factors

Financial implications of renewable and conventional energy

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

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

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

Evaluation planning tools such as PESTLE analysis

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Explore potential renewable energy resources, including current storage and generation technologies		<b>D1</b> Provide supported and well justified recommendations for the adoption of the most widely used conventional and non-conventional renewable energy resources
<b>P1</b> Create schematic diagrams showing the working principle of the most widely used renewable energy systems	<b>M1</b> Explore the rates of adoption of the most widely used renewable energy resources	
<b>LO2</b> Determine the optimum combination and efficiencies of renewable energy technologies for a particular location		<b>D2</b> Summarise the efficiencies of a variety of combinations of renewable energy technologies for a chosen location
<b>P2</b> Describe how each renewable energy system could be connected with local energy systems	<b>M2</b> Discuss how renewable energy systems will bring benefit to the people living in the chosen area	
<b>LO3</b> Conduct a cost-benefit analysis to determine the most viable option between renewable and conventional energy sources		<b>D3</b> Conduct a cost-benefit critical analysis to determine the most viable option between all available renewable and conventional energy sources
<b>P3</b> Calculate the installation and construction costs of one renewable energy system from a renewable energy standpoint	<b>M3</b> Contrast the installation and construction costs of all available renewable energy sources	

Pass	Merit	Distinction
<p><b>LO4</b> Explain socio-economic, legislative and environmental factors involved in the consideration and selection of other approaches to renewable energy resources and technologies</p>		<p><b>D4</b> Provide supported and justified recommendations and original ideas for an effective environmental analysis of alternative approaches to the selection of renewable energy resources</p>
<p><b>P4</b> Examine how socioeconomic, legislative and environmental factors affect the selection, set-up and operation of renewable energy sources</p>	<p><b>M4</b> Evaluate environmental analysis and planning tools such as PESTLE to identify possible sources of conflicts of interest</p>	

## Recommended Resources

### Textbooks

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

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

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

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

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

### Journals

*Renewable Energy Focus Journal*.

*The Open Renewable Energy Journal*.

*Journal of Renewable and Sustainable Energy*.

*Renewable Energy: An International Journal*.

### Websites

<https://www.theguardian.com>

The Guardian  
Renewable energy  
(Articles)

<http://www.energysavingtrust.org.uk/>

Energy Saving Trust  
Renewable energy  
(General Reference)

<http://www.gov.uk/>

Gov.UK  
Department of Energy & Climate Change  
(General Reference)

### Links

This unit links to the following related units:

*Unit 4: Managing a Professional Engineering Project*

*Unit 44: Industrial Power, Electronics and Storage*

*Unit 51: Sustainability*



# Unit 6: Mechatronics

<b>Unit code</b>	<b>T/615/1480</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

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

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

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

## Learning Outcomes

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

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

## Essential Content

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

#### *Origins and evolution:*

History and early development, evolution

Practical examples and extent of use

Current operational abilities and anticipated improvements

#### *Systems characteristics:*

Design of systems in an integrated way

Sensor and transducer types used

Consideration of component compatibility

Constraints on size and cost

Control device requirements and examples of applications

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

#### *Systems specifications:*

British and/or European standards relevant to application

Sensor types and interfacing

Actuator technology availability and selection

Selection and use of appropriate control software/devices.

Consideration of the interaction of system variables

System commissioning parameters

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

#### *Operation and functions:*

Simulation and modelling software functions

System function and operation

Modes of operation simulation, loading and surges

Advantages and disadvantage of software simulation

#### **LO4 Identify and correct faults in a mechatronic system**

*Locating and correcting system faults:*

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

Original system correct function and operation

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

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Examine the design and operational characteristics of a mechatronic system		<b>D1</b> Investigate an actual mechatronics system specification to propose alternative solutions
<b>P1</b> Describe the key components of a given mechatronics system  <b>P2</b> Identify the types of actuators, sensors and transducers used in the mechatronics system	<b>M1</b> Explore how the mechatronics components operate as part of an integrated system  <b>M2</b> Investigate the methods of control used by mechatronics systems	
<b>L02</b> Design a mechatronic system specification for a given application		<b>D2</b> Evaluate the operational capabilities and limitations of the mechatronics system design specification produced
<b>P3</b> Select the relevant sensor and the appropriate actuator technologies and produce a design specification suitable for these selections	<b>M3</b> Justify the sensor and actuator technologies selected with reference to available alternatives	
<b>L03</b> Examine the operation and function of a mechatronics system using simulation and modelling software		<b>D3</b> Explain the function and operation of a simulated mechatronics system
<b>P4</b> Demonstrate industry standard mechatronics simulation/modelling software	<b>M4</b> Describe the advantages and disadvantages of the software simulation	

Pass	Merit	Distinction
<b>LO4</b> Identify and correct faults in a mechatronic system		<b>D4</b> Investigate the causes of faults on a mechatronics system and suggest alternatives to the design specification to improve reliability
<b>P5</b> Explain the safe use of fault finding test equipment	<b>M5</b> Apply and document the correct use of fault finding techniques/ methods	
<b>P6</b> Locate and rectify faults on a mechatronic system		

## Recommended Resources

### Textbooks

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

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

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

RAMACHANDRAN, K.P., VIJAYARAGHAVAN, G.K. and BALASUNDARAM, M.S. (2008) *Mechatronics: Integrated Mechanical Electronic Systems*. India: Wiley.

### Journals

*International Journal of Advanced Mechatronic Systems*.

### Links

This unit links to the following related units:

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

*Unit 54: Further Control Systems Engineering*

# Unit 7: Machining and Processing of Engineering Materials

**Unit code** A/615/1481

**Unit level** 4

**Credit value** 15

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## Introduction

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

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

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

## Learning Outcomes

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

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



## Essential Content

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

#### *Conventional processes:*

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

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

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

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

Safe working practices when operating machining and process forming equipment

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

#### *Material choice and machine process:*

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

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

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

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

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

*Awareness of the range of cutting tools:*

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

Properties for cutting tool materials

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

*Cutting forces and the mechanics of chip formation:*

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

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

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

Work-holding: six degrees of freedom

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

*Moulding and shaping processes:*

Range of metal and ceramic powder moulding and shaping processes

Casting, powder metallurgy and sintering

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

*Range, benefits and limitations of various shaping processes:*

Extrusion, forging, rolling, hot and cold presswork

*Range of casting processes:*

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Explore the conventional machining and forming processes and their application in the production of engineered components		<b>D1</b> Determine the benefits and limitations of components manufactured using conventional machining and moulding processes
<b>P1</b> Describe the most appropriate machining process to manufacture a selected product  <b>P2</b> Explain why a specific machining process would be used to manufacture a selected component	<b>M1</b> Examine the characteristics of conventional machining processes, plastic moulding processes and powder metallurgy	
<b>L02</b> Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process		<b>D2</b> Review the structure and mechanical properties of a given engineered aluminium alloy component, manufactured using the die casting process and conventional material removal machining processes
<b>P3</b> Describe how the manufacturing process can affect the structure and properties of the parent material  <b>P4</b> Describe the effect lubricants, coolants and cutting fluids have on tooling, production speed, and quality of finish	<b>M2</b> Detail the characteristics of cutting tool geometries  <b>M3</b> Explain why different tool geometries are required for polymer, composite and carbon steel materials	

Pass	Merit	Distinction
<b>LO3</b> Identify the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component	<b>M4</b> Explain the properties and applications of ceramics tools and cubic boron nitride tools	<b>D3</b> Examine the relationship between cutting speed and tool life on the economics of metal removal
<b>P5</b> Review the parameters of metal removal that determine the appropriate tooling for the production of a given engineered component  <b>P6</b> Describe the six modes of cutting tool failure		
<b>LO4</b> Identify the most appropriate moulding and shaping process used to produce a range of metal and non-metal engineered components	<b>M5</b> Explain each of the stages of the ceramic powder moulding process and comment on the benefits associated with this manufacturing process	<b>D4</b> Investigate how the composition and structure of metal alloys, polymers and polymer matrix composites are affected by the material machining or forming process
<b>P7</b> Explain which material characteristics determine the choice of plastic moulding process  <b>P8</b> Describe the benefits and limitations of products manufactured by the sintering process		

## Recommended Resources

### Textbooks

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

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

### Journals

*Journal of Materials: Design and Applications*.

### Websites

<http://www.machinery.co.uk/>

Machinery  
(General Reference)

<http://www.materialsforengineering.co.uk/>

Engineering Materials  
Online Magazine  
(E-Magazine)

### Links

This unit links to the following related units:

*Unit 9: Materials, Properties and Testing*

*Unit 10: Mechanical Workshop Practices*

## Unit 8:

# Mechanical Principles

<b>Unit code</b>	<b>F/615/1482</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

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

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

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

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

### Learning Outcomes

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

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

## Essential Content

### LO1 Identify solutions to problems within static mechanical systems

#### *Shafts and beams:*

The effect of shear forces on beams

Bending moments and stress due to bending in beams

Selection of appropriate beams and columns to satisfy given specifications

The theory of torsion in solid and hollow circular shafts

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

#### *Energy and work:*

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

Linear and angular velocity and acceleration

Velocity and acceleration diagrams of planar mechanisms

Gyroscopic motion

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

#### *Simple systems:*

Parameters of simple and compounded geared systems

Efficiency of lead screws and screw jacks

#### *Couplings and energy storage:*

Universal couplings and conditions for constant-velocity

Importance of energy storage elements and their applications

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

*Types of motion:*

Simple harmonic motion

Natural frequency of vibration in mass-spring systems

*Damped systems:*

Frequency of damped vibrations in mass-spring-damper systems

The conditions for an external force to produce resonance



## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Identify solutions to problems within static mechanical systems		<b>D1</b> Calculate the magnitude of shear force and bending moment in cantilever and encasté beams for a variety of applications
<b>P1</b> Calculate the distribution of shear force, bending moment and stress due to bending in simply supported beams  <b>P2</b> Justify the selection of standard rolled steel sections for beams and columns  <b>P3</b> Determine the distribution of shear stress and the angular deflection due to torsion in solid and hollow circular shafts	<b>M1</b> Determine the material of a circular bar from experimental data of angle of twist obtained from a torsion test	
<b>LO2</b> Illustrate the effects that constraints have on the performance of a dynamic mechanical system		<b>D2</b> Calculate solutions of velocities and accelerations within planar mechanisms using trigonometric methodology
<b>P4</b> Explain the effects of energy transfer in mechanical systems with uniform acceleration present  <b>P5</b> Identify the magnitude and effect of gyroscopic reaction torque	<b>M2</b> Construct diagrams of the vector solutions of velocities and accelerations within planar mechanisms	

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

## Recommended Resources

### Textbooks

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 1: Engineering Design*

*Unit 2: Engineering Maths*

*Unit 36: Advanced Mechanical Principles*

# Unit 9: **Materials, Properties and Testing**

**Unit code** J/615/1483

**Unit level** 4

**Credit value** 15

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## **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

Preventative measures that can be used to extend service life.

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Explain the relationship between the atomic structure and the physical properties of materials		<b>D1</b> Explain how composition and structure of materials influence the properties of the parent material across the material's range
<p><b>P1</b> Describe the crystalline structure of the body-centred cubic cell, face-centred cubic cell and hexagonal close packed cell</p> <p><b>P2</b> Identify the different material properties that are associated with amorphous and crystalline polymer structures</p>	<p><b>M1</b> Describe physical, mechanical, electrical and thermal material properties, identifying practical applications for each property if it were to be used in an engineering context</p>	
<b>L02</b> Determine the suitability of engineering materials for use in a specified role		<b>D2</b> Explain why the behaviour of materials is considered such an important factor when selecting a material for a given product or application
<p><b>P3</b> Provide a list of the four materials categories, including an example of a product and application for each material identified</p> <p><b>P4</b> Identify the specific characteristics related to the behaviour of the four categories of engineering materials</p>	<p><b>M2</b> Describe, with examples, the effect heat treatment and mechanical processes have on material properties</p>	



Pass	Merit	Distinction
<p><b>L03</b> Explore the testing techniques to determine the physical properties of an engineering material</p>		<p><b>D3</b> 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</p>
<p><b>P5</b> Describe the six most common tests used to identify material properties</p> <p><b>P6</b> Describe the non-destructive testing processes – dye penetrant, magnetic particle, ultrasonic and radiography – and include an example application for each</p>	<p><b>M3</b> Explain how test results influence material selection for a given application</p>	
<p><b>L04</b> Recognise and categorise the causes of in-service material failure</p>		<p><b>D4</b> Explain the methods that could be used for estimating product service life when a product is subject to creep and fatigue loading</p>
<p><b>P7</b> Describe six common mechanisms of failure</p> <p><b>P8</b> Describe working and environmental conditions that lead to failure for a product made from material from each of the four material categories</p>	<p><b>M4</b> Explain, with examples, the preventative measures that can be used to extend the service life of a given product within its working environment</p>	

## Recommended Resources

### Textbooks

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

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

### Links

This unit links to the following related units:

*Unit 1: Engineering Design*

*Unit 10: Mechanical Workshop Practices*

# Unit 10: Mechanical Workshop Practices

**Unit code** L/615/1484

**Unit level** 4

**Credit value** 15

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## Introduction

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

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

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

## **Learning Outcomes**

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

1. Identify the potential hazards that exist when operating machine tools and bench fitting equipment, with reference to the appropriate health and safety regulations and risk assessment criteria.
2. Operate a manual lathe and milling machine to produce dimensionally accurate engineering components.
3. Interpret information from engineering drawings and operate measuring tools and work-holding equipment to check dimensional accuracy of machined components.
4. Explain mechanical measurement and quality control processes.

## Essential Content

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

#### *Safety compliance:*

Importance of, and responsibility for, safe working practice

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

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

Risk assessment of bench fitting and machining activities

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

#### *Operation:*

Factors influencing machining operations

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

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

Speeds and feeds to suit material properties and application

Use of work-holding jigs and fixtures

Removing material within dimensional tolerances

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

*Drawings function:*

Types of engineering drawing and their use

Developing proficiency in reading and extracting information from mechanical engineering drawings

Types of measuring tools

Characteristics of measurement tools for inspecting parts

Preparing quality control and inspection reports

**LO4 Explain the types and use of mechanical measurement and quality control processes**

*Control processes:*

Types of production quality control processes, metrology techniques

Importance of quality checks on machined components

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

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<p><b>L01</b> Identify the potential hazards that exist when operating machine tools and bench fitting equipment with reference to the appropriate health and safety regulations and risk assessment criteria</p>		<p><b>D1</b> Interpret the key features of relevant health and safety regulations as applied to a machining workshop</p>
<p><b>P1</b> Identify the potential hazards that exist when operating machine tools and bench fitting equipment</p> <p><b>P2</b> Describe the safe working practices and procedures to be followed when preparing and using a manual lathe and milling machine</p>	<p><b>M1</b> Produce a risk assessment, identifying suitable control measures, prior to undertaking a machining activity</p>	
<p><b>L02</b> Operate a manual lathe and milling machine to produce dimensionally accurate engineering components</p>		<p><b>D2</b> Illustrate the operating parameters of the milling machine and lathe and describe the function and features of cutting tools, work and tool-holding devices</p>
<p><b>P3</b> Produce a dimensionally accurate component using a lathe and milling machine</p>	<p><b>M2</b> Calculate appropriate cutting speeds and feeds to suit material properties and application for a given component</p>	

Pass	Merit	Distinction
<p><b>L03</b> Interpret information from engineering drawings and operate measuring tools and work-holding equipment to check dimensional accuracy of machined components</p>		<p><b>D3</b> Examine, with reference to material properties and geometry, the criteria for selection of the appropriate tooling for machining components from engineering materials including aluminium alloy, stainless steel and titanium alloy</p>
<p><b>P4</b> Identify the information that is required from a drawing to plan, machine and check the accuracy of a complex engineering component</p> <p><b>P5</b> Describe the function of precision measuring equipment used to check the dimensional accuracy of machined components</p>	<p><b>M3</b> Explain the process of using a dial gauge indicator to set-up work-holding devices on a milling machine</p>	
<p><b>L04</b> Explain the types and use of mechanical measurement and quality control processes</p>		<p><b>D4</b> Illustrate why the process of machining data collection and analysis is of critical importance to a production engineering company</p>
<p><b>P6</b> Explain the purpose of an engineering metrology laboratory and list the equipment found in a typical such lab</p>	<p><b>M4</b> Determine the function of the metrology equipment, surface testing, profile projectors, video measuring, interferometer, SIP measuring equipment, coordinate measuring machines (CMM) and 3D scanners</p>	



## Recommended Resources

### Textbooks

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

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

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

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

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

### Journals

*International Journal of Metrology and Quality Engineering*.

*Metrology Journal*.

### Links

This unit links to the following related units:

*Unit 9: Materials, Properties and Testing*

*Unit 14: Production Engineering for Manufacture*

# Unit 11:

# Fluid Mechanics

<b>Unit code</b>	<b>R/615/1485</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

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

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

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

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

## Learning Outcomes

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

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

## Essential Content

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

#### *Pressure and force:*

How Pascal's laws define hydrostatic pressure

Pressure with the use of manometers

Transmission of force in hydraulic devices

#### *Submerged surfaces:*

Determining thrust on immersed surfaces

Moments of area and parallel axis theorem

Calculating centre of pressure with moments of area

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

#### *Viscosity in fluids:*

Dynamic and kinematic viscosity definitions

Characteristics of Newtonian fluids

Effects of temperature on viscosity

Classification of non-Newtonian fluids

#### *Operating principles and limitations:*

Operating principles of viscometers

Converting results acquired from viscometers into viscosity values

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

#### *Fluid flow theory:*

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

Classification of fluid flow using Reynolds numbers

Calculations of flow within pipelines

Head losses that occur within a fluid flowing in a pipeline

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

#### *Aerodynamics:*

Application of prior theory of fluid flow to aerodynamics

Principles of aerofoils and how drag induces lift

Flow measuring devices and their operating principles

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

#### *Hydraulic machinery:*

Operating principles of different types of water turbine

Reciprocating and centrifugal pump theory

Efficiencies of these different types of hydraulic machinery

Environmental concerns surrounding hydraulic machines

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Determine behavioural characteristics of static fluid systems		<b>D1</b> Explain the use and limitations of manometers to measure pressure
<p><b>P1</b> Describe force and centre of pressure on submerged surfaces</p> <p><b>P2</b> Carry out appropriate calculations on force and centre of pressure on submerged surfaces</p>	<p><b>M1</b> Determine the parameters of hydraulic devices that are used in the transmission of force</p>	
<b>L02</b> Examine the operating principles and limitations of viscosity measuring devices		<b>D2</b> Illustrate the results of a viscosity test on a Newtonian fluid at various temperatures with that which is given on a data sheet and explain discrepancies.
<p><b>P3</b> Explain the operation and constraints of different viscometers that quantify viscosity in fluids</p> <p><b>P4</b> Carry out appropriate calculations on the effect of changes in temperature and other constraints on the viscosity of a fluid</p>	<p><b>M2</b> Explain, with examples, the effects of temperature and shear forces on Newtonian and non-Newtonian fluids</p>	

Pass	Merit	Distinction
<b>L03</b> Investigate dynamic fluid parameters of real fluid flow		<b>D3</b> Determine the head losses accumulated by a fluid when flowing in a pipeline for various applications
<b>P5</b> Determine parameters of a flowing fluid using Bernoulli's Equation  <b>P6</b> Define the flow of a fluid using Reynold's numbers and the significance of this information	<b>M3</b> Explain the effect of aerodynamic drag and lift on aerofoils	
<b>L04</b> Explore the operating principles and efficiencies of hydraulic machines		<b>D4</b> Describe and analyse the arguments concerning the ecological impact of hydroelectric power.
<b>P7</b> Determine the efficiency of a water turbine  <b>P8</b> Calculate the input power requirements of centrifugal pumps	<b>M4</b> Identify the limitations that exist within different types of water turbine	

## Recommended Resources

### Textbook

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

### Journals

*Journal of Fluid Mechanics*. Cambridge University Press.

*Annual Review of Fluid Mechanics*. Annual Reviews, California.

### Websites

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

### Links

This unit links to the following related units:

*Unit 29: Electro, Pneumatic and Hydraulic Systems*

*Unit 64: Thermofluids*

# Unit 12: Engineering Management

<b>Unit code</b>	<b>Y/615/1486</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

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

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

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

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



## **Learning Outcomes**

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

1. Examine the application of management techniques, and cultural and leadership aspects to engineering organisations.
2. Explore the role of risk and quality management in improving performance in engineering organisations.
3. Investigate the theories and tools of project and operations management when managing activities and optimising resource allocation.
4. Perform activities that improve current management strategies within an identified element of an engineering organisation.

## Essential Content

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

*Main concepts and theories of management and leadership:*

Influence on organisational culture and communication practices

Effect of change within an organisation on its culture and behaviour

*Management and leadership theories:*

Management and leadership theories

Managerial behaviour and effectiveness

Organisational culture and change

Organisational communication practices

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

*Fundamentals of quality management:*

Introduction to monitoring and controlling

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

*Risk and quality management:*

Risk management processes

Risk mapping and risk matrix

Quality management theories

Continuous improvement practices

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

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

*Operation management:*

Main areas and stages of projects and operations management

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

*Project and operations management theories and tools:*

Project appraisal and life cycle

Logistics and supply chain management

Operations management

Resources management

Sustainability

Legal requirements governing employment, health, safety and environment

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

*The key success of management strategies:*

Following processes from end to end, from suppliers to customers

Identifying areas critical for the success of a project or process

*Planning tools:*

Gantt charts

Flow charts

Critical analysis and evaluation

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Examine the application of management techniques, and cultural and leadership aspects to engineering organisations		<b>D1</b> Propose recommendations for the most efficient application of management techniques
<b>P1</b> Explain management and leadership theories and techniques used within engineering organisations	<b>M1</b> Justify different management techniques with emphasis on cultural and leadership aspects and their applications to engineering organisations	
<b>L02</b> Explore the role of risk and quality management in improving performance in engineering organisations		<b>D2</b> Provide supported and justified recommendations for the most efficient and effective risk and quality management practices
<b>P2</b> Describe the role and importance of risk and quality management processes and their impact on engineering organisations	<b>M2</b> Explain how risk and quality management strategies encourage performance improvements within engineering organisations	
<b>L03</b> Investigate the theories and tools of project and operations management when managing activities and optimising resource allocation		<b>D3</b> Analyse the relative merits of theories and tools of project and operations management, with a focus on their relevance when managing activities and optimising resource allocation
<b>P3</b> Identify project and operations management tools used when managing activities and resources within the engineering industry	<b>M3</b> Analyse the most effective project and operations management tools used when managing activities and optimising resource allocation	

Pass	Merit	Distinction
<b>LO4</b> Perform activities that improve current management strategies within an identified element of an engineering organisation		<b>D4</b> Conduct a full analysis of the management processes within an engineering organisation (or case study) and make fully justified recommendations for improvements to the management strategies
<b>P4</b> Define the range of processes available to improve management processes within an engineering organisation	<b>M4</b> Explore activities that will improve management strategies within an engineering organisation	

## Recommended Resources

### Textbooks

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

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

OAKLAND, J.S. (2015) *Statistical Process Control*. 6th Ed. Routledge.

### Websites

<http://strategicmanagement.net/> Strategic Management Society  
(General Reference)

<http://www.journals.elsevier.com/> Elsevier  
Journal of Operations Management  
(Journal)

<http://www.emeraldgrouppublishing.com> Emerald Publishing  
International Journal of Operations &  
Production Management  
(e-Journal)

### Links

This unit links to the following related units:

*Unit 4: Managing a Professional Engineering Project*

*Unit 35: Professional Engineering Management*

# Unit 13: Fundamentals of Thermodynamics and Heat Engines

<b>Unit code</b>	<b>D/615/1487</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

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

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

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

## Learning Outcomes

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

1. Investigate fundamental thermodynamic systems and their properties.
2. Apply the Steady Flow Energy Equation to plant equipment.
3. Examine the principles of heat transfer to industrial applications.
4. Determine the performance of internal combustion engines.

## Essential Content

### LO1 Investigate fundamental thermodynamic systems and their properties

#### *Fundamental systems:*

Forms of energy and basic definitions

Definitions of systems (open and closed) and surroundings

First law of thermodynamics

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

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

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

### LO2 Apply the Steady Flow Energy Equation to plant equipment

#### *Energy equations:*

Conventions used when describing the behaviour of heat and work

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

Assumptions, applications and examples of practical systems

Steady Flow Energy Equation as applied to open systems

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



### **LO3 Examine the principles of heat transfer to industrial applications**

#### *Principles of heat transfer:*

Modes of heat transmission, including conduction, convection & radiation

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

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

Regenerators

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

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

#### *Performance:*

Application of the second law of thermodynamics to heat engines

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

Explanations of practical applications of heat engine cycles, such as compression ignition (CI) and spark ignition engines, including their relative mechanical and thermodynamic efficiencies

Describe possible efficiency improvements to heat engines

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Investigate fundamental thermodynamic systems and their properties		<b>D1</b> Illustrate the importance of expressions for work done in thermodynamic processes by applying first principles
<p><b>P1</b> Describe the operation of thermodynamic systems and their properties</p> <p><b>P2</b> Explain the application of the first law of thermodynamics to appropriate systems</p> <p><b>P3</b> Explain the relationships between system constants for a perfect gas</p>	<b>M1</b> Calculate the index of compression in polytropic processes	
<b>LO2</b> Apply the Steady Flow Energy Equation to plant equipment		<b>D2</b> Produce specific Steady Flow Energy Equations based on stated assumptions in plant equipment
<p><b>P4</b> Explain system parameters using the Non-Flow Energy Equation</p> <p><b>P5</b> Apply the Steady Flow Energy Equation to plant equipment</p>	<b>M2</b> Derive the Steady Flow Energy Equation from first principles	

Pass	Merit	Distinction
<b>LO3</b> Examine the principles of heat transfer to industrial applications		<b>D3</b> Distinguish the differences between parallel and counter flow recuperator heat exchangers
<b>P6</b> Determine the heat transfer through composite walls  <b>P7</b> Apply heat transfer formulae to heat exchangers	<b>M3</b> Explore heat losses through lagged and unlagged pipes	
<b>LO4</b> Determine the performance of internal combustion engines		<b>D4</b> Evaluate the performance of two stroke and four stroke diesel engines
<b>P8</b> Describe with the aid of a PV (pressure volume) diagram the operational sequence of four stroke spark ignition and four stroke compression ignition engines.  <b>P9</b> Explain the mechanical efficiency of two and four stroke engines	<b>M4</b> Review the relative efficiency of ideal heat engines operating on the Otto and Diesel cycles	

## Recommended Resources

### Textbooks

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

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

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

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

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

### Links

This unit links to the following related units:

*Unit 38: Further Thermodynamics*

# Unit 14: Production Engineering for Manufacture

**Unit code** H/615/1488

**Unit level** 4

**Credit value** 15

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## 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

Pass	Merit	Distinction
<p><b>LO1</b> Illustrate the role and purpose of production engineering and its relationship with the other elements of a manufacturing system</p>		<p><b>D1</b> Analyse how the production engineer supports the development of operational strategies to achieve production and financial objectives</p>
<p><b>P1</b> Describe the multiple elements of a modern manufacturing system</p> <p><b>P2</b> Explain the role of the production engineer within a manufacturing system</p>	<p><b>M1</b> Investigate how the production engineer can influence the design process and refine products, services and systems</p>	
<p><b>LO2</b> Select the most appropriate production processes and associated facility arrangements for manufacturing products of different material types</p>		<p><b>D2</b> Evaluate how the choice of bonding and jointing processes influence both the product design and the selection of the most effective production process</p>
<p><b>P3</b> Examine the properties and applications of ceramic products manufactured using the sintering, hot pressing, chemical vapour deposition (CVD) and reaction bonding processes</p> <p><b>P4</b> Describe the properties and applications of composite products manufactured using manual and automated layup, filament winding, pultrusion and resin transfer moulding processes</p>	<p><b>M2</b> Discuss the benefits associated with polymer manufacturing process</p>	

Pass		Merit	Distinction
<b>LO3</b> Analyse how a production system can incorporate a number of different production processes for a given product or assembly		<b>M3</b> Explain how materials, components and sub-assembly handling and conveyance can impact on the effectiveness and efficiency of a modern manufacturing plant	<b>D3</b> 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
<b>P5</b> Review the type and sequence of production processes a product or component would follow from initial design through to manufacture and distribution	<b>P6</b> Describe the function of the various production facilities within a modern manufacturing plant		
<b>LO4</b> Explore the effectiveness of a production system in terms of its operation within the wider manufacturing system		<b>M4</b> Explain the immediate and long term effects that production errors and rectification can have on a manufacturing company	<b>D4</b> Analyse the criteria by which production performance can be measured within the wider manufacturing system
<b>P7</b> Review the type of data that would be collected and analysed to measure production performance	<b>P8</b> Describe the measures that can improve production performance criteria		

## Recommended Resources

### Textbooks

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

### Websites

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

### Links

This unit links to the following related units:

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

*Unit 48: Manufacturing Systems Engineering*

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

**Unit code** K/615/1489

**Unit level** 4

**Credit value** 15

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## Introduction

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

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

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

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

## **Learning Outcomes**

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

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

## Essential Content

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

*System operational characteristics:*

Modular, unitary and rack mounted systems

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

Input and output devices (digital, analogue)

Interface requirements

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

Internal architecture

Different types of programming languages (IEC 61131-3)

### LO2 Design a simple PLC program by considering PLC information, programming and communication techniques

*Programming language:*

Signal types

Number systems (binary, octal, hexadecimal)

Allocation lists of inputs and outputs

Communication techniques

Network methods

Logic functions (AND, OR, XOR)

Associated elements (timers, counters, latches)

*Test and debug methods:*

Systematic testing and debugging methods

Proper application of appropriate testing and debugging methods

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

*Element considerations:*

Types of robots

Mobile robotics

Tools and end effectors

Programming methods

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

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

*Safety:*

Cell safety features

Operating envelope

Operational modes

User interfaces

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Describe the design and operational characteristics of a PLC system		<b>D1</b> Analyse the internal architecture of a typical PLC to determine its operational applications
<p><b>P1</b> Describe the key differences of PLC construction styles and their typical applications</p> <p><b>P2</b> Determine the types of PLC input and output devices available</p> <p><b>P3</b> Describe the different types of communication links used with PLCs</p>	<p><b>M1</b> Explain the different types of PLC programming languages available</p>	
<b>L02</b> Design a simple PLC program by considering PLC information, programming and communication techniques		<b>D2</b> Produce all elements of a PLC program for a given industrial task and analyse its performance
<p><b>P4</b> Design and describe the design elements that have to be considered in the preparation of a PLC programme program</p> <p><b>P5</b> Explain how communication connections are correctly used with the PLC</p>	<p><b>M2</b> Examine the methods used for testing and debugging the hardware and software</p>	



Pass	Merit	Distinction
<b>L03</b> Describe the key elements of industrial robots and be able to program them with straightforward commands to perform a given task		<b>D3</b> Design and produce a robot program for a given industrial task
<p><b>P6</b> Describe the types of industrial robots and their uses in industry</p> <p><b>P7</b> Describe the types of robot end effectors available and their applications</p>	<b>M3</b> Investigate a given industrial robotic system and make recommendations for improvement	
<b>L04</b> Investigate the design and safe operation of a robot within an industrial application		<b>D4</b> Design a safe working plan for an industrial robotic cell in a given production process to include a full risk assessment
<b>P8</b> Investigate the safety systems used within an industrial robotic cell	<b>M4</b> Analyse how the systems in place ensure safe operation of a given industrial robotic cell	

## Recommended Resources

### Textbooks

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

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

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

### Websites

<a href="http://www.plcmanual.com/">http://www.plcmanual.com/</a>	PLC Manual (General Reference)
<a href="http://www.plcs.net/">http://www.plcs.net/</a>	PLC Programming Info (General Reference)
<a href="http://www.learnaboutrobots.com/">http://www.learnaboutrobots.com/</a>	Learn About Robots Industrial Robots (General Reference)

### Links

This unit links to the following related units:

*Unit 6: Mechatronics*

*Unit 42: Further Programmable Logic Controllers (PLCs)*

# Unit 16: Instrumentation and Control Systems

<b>Unit</b>	<b>D/615/1490</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## 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
<b>LO1</b> Identify the instrumentation systems and devices used in process control		<b>D1</b> Critically review the industrial application of an instrumentation and control process system, using research evidence
<b>P1</b> Define the types of sensor and transducers used in process control	<b>M1</b> Explore industrial applications for sensors and transducers	
<b>P2</b> Describe how the sensors and transducers function	<b>M2</b> Analyse the accuracy of the sensors and transducers used in a particular application	
<b>P3</b> Define the signal terminology used in process control		
<b>P4</b> Explain the different methods and standards used in signal conversion and conditioning		
<b>LO2</b> Investigate process control systems and controllers		<b>D2</b> Develop a recommendation for improvement to process control systems and controllers
<b>P5</b> Describe the importance of process control systems	<b>M3</b> Explain a typical industrial application for a process control system	
<b>P6</b> Define the process controller terminology used in industrial applications		

Pass	Merit	Distinction
<b>L03</b> Analyse the control concepts used within a process		<b>D3</b> Analyse the effectiveness of the control concepts used within a given process and suggest improvements
<p><b>P7</b> Define the control terminology and concepts used in process control systems</p> <p><b>P8</b> Describe the system tuning methods and techniques employed to improve performance</p>	<p><b>M4</b> Explain the control terminology, concepts and tuning techniques used in a typical industrial application</p>	
<b>L04</b> Apply predicted values to ensure stability within a control system		<b>D4</b> Discuss why the system responds in a certain way as the signals are applied
<p><b>P9</b> Demonstrate the correct use of an instrumentation and control virtual simulation</p>	<p><b>M5</b> Show how the virtual control system responds to a range of signal inputs</p>	



## Recommended Resources

### Textbooks

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

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

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

### Journals

*Journal of Process Control*.

### Links

This unit links to the following related units:

*Unit 40: Commercial Programming Software*

*Unit 54: Further Control Systems Engineering*

# Unit 17: Quality and Process Improvement

<b>Unit code</b>	<b>H/615/1491</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## 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 statistical process control (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, business 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
<b>LO1</b> Illustrate the applications of statistical process control when applied in an industrial environment to improve efficiency		<b>D1</b> Suggest justified recommendations for the application of statistical process control in an industrial environment to improve efficiency
<b>P1</b> Review the tools and techniques used to support quality control  <b>P2</b> Describe the processes and applications of statistical process control in industrial environments	<b>M1</b> Explain the role and effectiveness of the quality tools and techniques used within an industrial environment	
<b>LO2</b> Analyse cost effective quality control tools		<b>D2</b> Develop a process for the application of an extensive range of quality control tools and techniques with emphasis on costing
<b>P3</b> Analyse the effective use of quality control tools and techniques  <b>P4</b> Analyse costing techniques used within industry	<b>M2</b> Determine with justification the quality control tools and techniques that could be used to improve business performance	
<b>LO3</b> Determine the role of standards in improving efficiency, meeting customer requirements and opening up new opportunities for trade		<b>D3</b> Illustrate a plan for the application of international standards that would improve efficiency, meet customer requirements and open up new opportunities for trade
<b>P5</b> Determine required standards to improve efficiency, meet customer requirements and open up new opportunities for trade	<b>M3</b> Discuss the importance of standards applied in the engineering environment	

Pass	Merit	Distinction
<p><b>LO4</b> Analyse the importance of Total Quality Management and continuous improvement in manufacturing and service environments</p>		<p><b>D4</b> 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</p>
<p><b>P6</b> Analyse the principles, tools and techniques of Total Quality Management and continuous improvement</p> <p><b>P7</b> Analyse how the concept of Total Quality Management and continuous improvement could help in delivering high quality performance within businesses</p>	<p><b>M4</b> 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</p>	

## Recommended Resources

### Textbooks

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

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

### Links

This unit links to the following related units:

*Unit 49: Lean Manufacturing*



# Unit 18: Maintenance Engineering

**Unit code** K/615/1492

**Unit level** 4

**Credit value** 15

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## 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

Pass	Merit	Distinction
<b>L01</b> Analyse the impact of relevant statutory regulations and organisational safety requirements in the industrial workplace		<b>D1</b> Determine the likely consequences of non-adherence to relevant health and safety legislation by employers and employees <b>D2</b> Critically analyse the potential impact of a workplace inspection by a Health and Safety Executive inspector
<b>P1</b> Describe the key features of health and safety regulations in the workplace <b>P2</b> Explain the role of the Health and Safety Executive in health and safety in the workplace	<b>M1</b> Analyse the consequences of employers not abiding by health and safety legislation and regulations in the workplace	
<b>L02</b> Differentiate between the merits and use of different types of maintenance strategies in an industrial workplace		<b>D3</b> Illustrate the most appropriate maintenance system in an industrial workplace <b>D4</b> Assess the likely consequences of not completing a maintenance regime in an industrial workplace
<b>P3</b> Describe the methods used to complete engineering maintenance in an industrial workplace <b>P4</b> Discuss the advantages and disadvantages of different strategies to complete maintenance in an industrial workplace	<b>M2</b> Explain the importance of carrying out engineering maintenance in an industrial workplace	

Pass	Merit	Distinction
<p><b>LO3</b> Illustrate competence in working safely by correctly identifying the hazards and risks associated with maintenance techniques</p>	<p><b>M3</b> Discuss the importance of completing risk assessments</p> <p><b>M4</b> Explain how control measures are used to prevent accidents</p> <p><b>M5</b> Complete a method statement for a typical maintenance technique</p>	<p><b>D5</b> 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</p>
<p><b>P5</b> Describe methods used to identify risks and their associated hazards</p>		
<p><b>P6</b> Carry out a risk assessment on a typical maintenance technique</p>		
<p><b>LO4</b> Apply effective inspection and maintenance techniques relative to a particular specialisation such as mechanical or electrical</p>		<p><b>D6</b> Justify appropriate inspection and maintenance techniques across industrial plant assets</p>
<p><b>P7</b> Apply effective inspection and maintenance techniques in an industrial or simulated environment, recording the appropriate sequence of procedures</p>	<p><b>M6</b> Analyse the effectiveness of these inspection and maintenance techniques in plant asset management</p>	

## Recommended Resources

### Textbooks

MOBLEY, K. (2014) *Maintenance Engineering Handbook*. 8th Ed. McGraw Hill.

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

### Websites

<http://www.soe.org.uk/> SOE Society of Operations Engineers  
IplantE  
(General Reference)

<http://www.imeche.org/> The Institution of Mechanical Engineers  
(General Reference)

### Links

This unit links to the following related units:

*Unit 30: Operations and Plant Management*

*Unit 4: Managing a Professional Engineering Project*

# Unit 19: Electrical and Electronic Principles

<b>Unit code</b>	<b>M/615/1493</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

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

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

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

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



## **Learning Outcomes**

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

1. Apply an understanding of fundamental electrical quantities to evaluate circuits with constant voltages and currents.
2. Evaluate circuits with sinusoidal voltages and currents.
3. Describe the basis of semiconductor action, and its application to simple electronic devices.
4. Explain the difference between digital and analogue electronics, describing simple applications of each.

## Essential Content

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

#### *Fundamental electrical quantities and concepts:*

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

#### *Circuit laws:*

Voltage sources, Ohm's law, resistors in series and parallel, the potential divider  
Kirchhoff's and Thevenin's laws; superposition

#### *Energy and power:*

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

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

#### *Fundamental quantities of periodic waveforms:*

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

#### *Mathematical techniques:*

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

#### *Reactive components:*

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

#### *Circuits with sinusoidal sources:*

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

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

*Ideal transformer and rectification:*

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

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

*Semiconductor material:*

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

*Simple semiconductor devices:*

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

*Simple semiconductor applications:*

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

Transistors: switches and signal amplifiers

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

*Analogue concepts:*

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

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

*Digital concepts:*

Logic circuits implemented with switches or relays

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

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

Truth Tables

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Apply an understanding of fundamental electrical quantities to analyse circuits with constant voltages and currents		<b>D1</b> Evaluate the operation of a range of circuits with constant sources, using relevant circuit theories.
<b>P1</b> Apply the principles of circuit theory to simple circuits with constant sources, to explain the operation of that circuit	<b>M1</b> Apply the principles of circuit theory to a range of circuits with constant sources, to explain the operation of that circuit	
<b>L02</b> Analyse circuits with sinusoidal voltages and currents		<b>D2</b> Analyse the operation and behaviour of series and parallel RLC circuits, including resonance and using the principles of circuit theory with sinusoidal sources.
<b>P2</b> Analyse series RLC circuits, using the principles of circuit theory with sinusoidal sources.	<b>M2</b> Analyse series and parallel RLC circuits, using the principles of circuit theory with sinusoidal sources.	
<b>L03</b> Describe the basis of semiconductor action, and its application to simple electronic devices		<b>D3</b> Analyse the performance of a range of discrete semiconductor devices in terms of simple semiconductor theory, and suggest applications for each.
<b>P3</b> Describe the behaviour of a p-n junction in terms of semiconductor behaviour <b>P4</b> Demonstrate the action of a range of semiconductor devices	<b>M3</b> Explain the operation of a range of discrete semiconductor devices in terms of simple semiconductor theory	

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

## Recommended Resources

### Textbooks

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

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

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

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

### Links

This unit links to the following related units:

*Unit 20: Digital Principles*

*Unit 22: Electronic Circuits and Devices*

*Unit 52: Further Electrical, Electronic and Digital Principles*

## Unit 20:

## Digital Principles

<b>Unit code</b>	<b>T/615/1494</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

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

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

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

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

## **Learning Outcomes**

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

1. Explain and analyse simple combinational logic circuits.
2. Explain and analyse simple sequential logic circuits.
3. Describe and evaluate the technologies used to implement digital electronic circuits.
4. Describe and analyse a range of digital subsystems, hence establishing the building blocks for larger systems.



## Essential Content

### LO1 Explain and analyse simple combinational logic circuits

#### *Concepts of combinational logic:*

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

#### *Number systems, and binary arithmetic:*

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

#### *Analysis of logic circuits:*

Truth Tables, Boolean Algebra, de Morgan's theorem, Karnaugh Maps  
Simplification and optimisation of circuits using these techniques

### LO2 Explain and analyse simple sequential logic circuits

#### *Sequential logic elements and circuits:*

SR latch built from NAND or NOR gates

Clocked and edge-triggered bistables, D and JK types

Simple sequential circuits, including shift registers and counters

Timing Diagrams

#### *Memory technologies:*

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

Relative advantages in terms of density, volatility and power consumption

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

**LO3 Describe and evaluate the technologies used to implement digital electronic circuits**

*Logic values represented by voltages:*

The benefit of digital representation of information

The concept of logic input and output values and thresholds

*Digital technologies:*

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

Programmable logic, FPGAs, relative advantages and applications

**LO4 Describe and analyse a range of digital subsystems, hence establishing the building blocks for larger systems**

*User interface:*

Examples to include switches, light emitting diodes and simple displays

*Digital subsystems:*

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Explain and analyse simple combinational logic circuits		<b>D1</b> Analyse, optimise and enhance combinational logic circuits, making best use of Truth Table, Boolean Algebra and Karnaugh Map
<b>P1</b> Explain and analyse the operation of a simple combinational logic circuit, making limited use of Truth Table, Boolean Algebra and Karnaugh Map	<b>M1</b> Analyse and optimise the operation of a combinational logic circuit making good use of Truth Table, Boolean Algebra and Karnaugh Map	
<b>LO2</b> Explain and analyse simple sequential logic circuits		<b>D2</b> Analyse, optimise and enhance a sequential logic circuit, making use of Timing Diagrams
<b>P2</b> Explain and analyse the operation of a simple sequential logic circuit, making use of Timing Diagrams	<b>M2</b> Analyse and optimise a simple sequential logic circuit, making use of Timing Diagrams	
<b>LO3</b> Describe and evaluate the technologies used to implement digital electronic circuits		<b>D3</b> Apply lab equipment to configure, test and evaluate digital circuits, comparing and evaluating characteristics of different technologies
<b>P3</b> Apply lab equipment to describe and evaluate simple digital circuits	<b>M3</b> Apply lab equipment to configure and test simple digital circuits	

Pass	Merit	Distinction
<b>LO4</b> Describe and analyse a range of digital subsystems, hence establishing the building blocks for larger systems		<b>D4</b> Describe and critically evaluate a range of different logic subsystems, comparing these with other techniques or subsystems available, indicating the place they might take in a larger system
<b>P4</b> Describe and analyse the principles of a range of different logic subsystems	<b>M4</b> Describe and analyse a range of different logic subsystems, indicating the place they might take in a larger system	

## Recommended Resources

### Textbooks

FLOYD, T.L. (2015) *Digital Fundamentals*. Pearson.

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

### Links

This unit links to the following related units:

*Unit 19: Electrical and Electronic Principles*

*Unit 22: Electronic Circuits and Devices*

*Unit 52: Further Electrical, Electronic and Digital Principles*

## Unit 21:

## Electrical Machines

<b>Unit code</b>	<b>A/615/1495</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

Electrical machines can be found in manufacturing, transport, consumer appliances and hospitals. People will come across them every day in their home and at work. They convert energy in three ways: transformers which change the voltage level of an alternating current; motors which convert electrical energy to mechanical energy; and generators which convert mechanical energy to electrical energy. Transducers and actuators are also energy converters, and can be found in a wide range of industrial and domestic applications.

This unit introduces students to the characteristics and operational parameters of a range of electromagnetic powered machines that are used in a variety of applications. Among the topics included in this unit are: principles underlying the operation and construction of transformers, induction motors, synchronous machines, electromagnetic transducers, actuators, and generators; and operating characteristics of electrical machines such as voltage, current, speed of operation, power rating, electromagnetic interference (EMI) and efficiency.

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

## **Learning Outcomes**

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

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

## Essential Content

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

#### *Constructional features:*

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

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

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

#### *Methods and applications:*

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

Types of electric motors and their practical applications

Starting methods

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

Cooling and protection devices

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

#### *Types of generators available:*

Construction, application, characteristics and testing of generators

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

Practical applications

Generation methods

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

Cooling and protection devices



#### LO4 **Analyse the operating characteristics of electromagnetic transducers and actuators**

*Operating characteristics:*

Construction, application, characteristics and testing of electromagnetic transducers and actuators

Transducer types (active, passive, sensor), actuator types (solenoids, linear, rotary)

Practical applications.

Voltage and current requirements, hysteresis and speed of operation

Torque

Insulation Protection (IP) rating

Contact types

Back Electromotive Force (EMF), EMI and efficiency

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Assess the constructional features and applications of transformers		<b>D1</b> Assess the efficiency of a number of available transformers and make a recommendation for an actual operational requirement
<b>P1</b> Examine the types of transformers available <b>P2</b> Discuss suitable applications for available transformers <b>P3</b> Discuss the different methods of connections available for three-phase transformers	<b>M1</b> Illustrate the operation of the transformer, considering the equivalent circuit	
<b>L02</b> Analyse the starting methods and applications of the three-phase induction motors and synchronous machines		<b>D2</b> Critically evaluate the efficiency of a number of available motors and make a recommendation for a specified operational requirement
<b>P4</b> Analyse the types of electrical motors available, discussing suitable applications <b>P5</b> Analyse the different methods of starting induction motors and synchronous machines	<b>M2</b> Justify the selection of a motor for a specific industrial application	
<b>L03</b> Investigate the types of generators available in the industry by assessing their practical application		<b>D3</b> Assess the efficiency of a number of available generators and make a recommendation for a specified operational requirement
<b>P6</b> Explain the types and construction of generators <b>P7</b> Identify a generator for a specific application, considering their characteristics	<b>M3</b> Justify the application of a specific type of generator	

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

## Recommended Resources

### Textbooks

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 43: Machines and Drives*

# Unit 22: Electronic Circuits and Devices

**Unit code** F/615/1496

**Unit level** 4

**Credit value** 15

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## Introduction

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

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

Among the topics included in this unit are: power amplifiers, class A, B and AB; operational amplifiers, inverting, non-inverting, differential, summing, integrator, differentiator; types such as open, closed, positive and negative feedback; frequency, stability, frequency drift, distortion, amplitude, wave shapes and testing procedures.

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

## **Learning Outcomes**

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

1. Determine the operational characteristics of amplifier circuits.
2. Investigate the types and effects of feedback on an amplifier's performance.
3. Examine the operation and application of oscillators.
4. Apply testing procedures to electronic devices and circuits.

## Essential Content

### LO1 Determine the operational characteristics of amplifier circuits

*Operational characteristics:*

Power amplifiers: class A, B and AB

Operational amplifiers: inverting, non-inverting, differential, summing, integrator, differentiator, comparator, instrumentation, Schmitt trigger, active filters

Gain, bandwidth, frequency response, input and output impedance

Distortion and noise

### LO2 Investigate the types and effects of feedback on an amplifier's performance

*Types and effects:*

Types including open, closed, positive and negative feedback

Effect of feedback on gain, bandwidth, distortion, noise, stability, input and output impedance

### LO3 Examine the operation and application of oscillators

*Operation and application:*

Types of oscillators such as Wien bridge, Twin-T, R-C ladder, L-C coupled, transistor, operational amplifier, crystal

Frequency, stability, frequency drift, distortion, amplitude and wave shapes

## LO4 **Apply testing procedures to electronic devices and circuits**

### *Testing procedures:*

Measuring performance, using practical results and computer simulations

Voltage gain, current, bandwidth, frequency response, output power, input and output impedance

Distortion and noise

### *Devices to test:*

Semiconductors

Integrated circuits

Amplifiers

Oscillators

Filters

Power supplies

Integrated circuit (IC) voltage regulators

Combined analogue and digital IC's

### *Component manufacturer's data:*

Specifications, manuals and circuit diagrams

### *Use of testing equipment:*

Meters, probes and oscilloscopes

Signal generators and signal analysers, logic analysers

Virtual test equipment



## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Determine the operational characteristics of amplifier circuits		<b>D1</b> Assess the results obtained from the application of practical and virtual tests on amplifier circuits studied
<b>P1</b> Describe the types of amplifiers available and their applications  <b>P2</b> Examine the different performance characteristics of types of amplifier	<b>M1</b> Explain the results obtained from applying practical tests on an amplifier's performance	
<b>L02</b> Investigate the types and effects of feedback on an amplifier's performance		<b>D2</b> Evaluate the results of practical and virtual tests to analyse the effect of feedback on an amplifier's performance
<b>P3</b> Examine the types of feedback available and their effect on the amplifier's performance  <b>P4</b> Describe a circuit which employs negative feedback	<b>M2</b> Perform practical tests to show the effect of feedback on an amplifier's performance	
<b>L03</b> Examine the operation and application of oscillators		<b>D3</b> Analyse the results obtained from applying practical and virtual tests on oscillators studied
<b>P5</b> Examine types of available oscillators and their applications	<b>M3</b> Assess the performance characteristics of types of oscillators	

Pass	Merit	Distinction
<b>LO4</b> Apply testing procedures to electronic devices and circuits		<b>D4</b> Analyse and compare the results obtained from applying practical and virtual tests on devices and circuits studied
<b>P6</b> Select suitable electronic devices and their parent circuits and identify the appropriate manufacturer's data sheets  <b>P7</b> Interpret relevant information from manufacturer's data when testing electronic devices and circuits	<b>M4</b> Perform tests on electronic devices and circuits, recording results and recommending appropriate action	

## Recommended Resources

### Textbooks

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

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 43: Machines and Drives*

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

**Unit code** J/615/1497

**Unit level** 4

**Credit value** 15

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## 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
<b>L01</b> Describe the key principles of manufacturing using a CAD/CAM system		<b>D1</b> Critically evaluate, using illustrative examples, the impact of different machining conditions and specifications on component manufacturing
<p><b>P1</b> Describe the hardware and software elements of a typical CAD/CAM system</p> <p><b>P2</b> Describe, with examples, the inputs and outputs of the CAD/CAM process</p> <p><b>P3</b> Explain the different methods of component set-up, work-holding and tooling available on CNC machines</p>	<p><b>M1</b> Analyse the suitability of different programming methods of CNC machines</p>	
<b>L02</b> Produce 3D solid models of a component suitable for transfer into a CAM system		<b>D2</b> Critically evaluate the effectiveness of using a CAD/CAM system and solid modelling to manufacture components
<p><b>P4</b> Design and produce a CAD solid model of a component to be manufactured on a CNC machine</p> <p><b>P5</b> Design a working drawing of a component containing specific manufacturing detail</p>	<p><b>M2</b> Assess the importance of using different geometry manipulation methods for efficient model production</p>	

Pass	Merit	Distinction
<b>L03</b> Use CAM software to generate manufacturing simulations of a component		<b>D3</b> Analyse the effect of applying different manufacturing techniques and modifications to achieve an optimised production time
<b>P6</b> Use CAM software to generate a geometrically accurate CAD solid model of a component	<b>M3</b> Using CAM software, generate cutter tool path simulations	
<b>L04</b> Design and produce a dimensionally accurate component on a CNC machine using a CAD/CAM system		<b>D4</b> Critically analyse, giving illustrative examples, the different methods of data transfer through a CAD/CAM system
<b>P7</b> Detail a part program for a component using CAM software and transfer the part program to a CNC machine and manufacture a component	<b>M4</b> Analyse different methods of component inspection used in manufacturing	
<b>P8</b> Describe the structural elements of a CNC Machining Centre		
<b>P9</b> Review a component manufactured on a CNC machine to verify its accuracy		

## Recommended Resources

### Textbooks

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

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

### Links

This unit links to the following related units:

*Unit 1: Engineering Design*

# Unit 29: Electro, Pneumatic and Hydraulic Systems

<b>Unit code</b>	<b>L/615/1498</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Hydraulics and pneumatics incorporate the importance of fluid power theory in modern industry. This is the technology that deals with the generation, control, and movement of mechanical elements or systems with the use of pressurised fluids in a confined system. In respect of hydraulics and pneumatics, both liquids and gases are considered fluids. Oil hydraulics employs pressurised liquid petroleum oils and synthetic oils, whilst pneumatic systems employ an everyday recognisable process of releasing compressed air to the atmosphere after performing the work.

The aim of this module is to develop students' knowledge and appreciation of the applications of fluid power systems in modern industry. Students will investigate and design pneumatic, hydraulic, electro-pneumatic and electro-hydraulic systems. This unit offers the opportunity for students to examine the characteristics of fluid power components and evaluate work-related practices and applications of these systems.

On successful completion of this unit students will be able to explain applications of hydraulic and pneumatic systems in the production industry, determine the fundamental principles and practical techniques for obtaining solutions to problems, appreciate real-life applications of pneumatic and hydraulic systems, and investigate the importance of structured maintenance techniques.

## Learning Outcomes

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

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

## Essential Content

### LO1 Calculate the parameters of pneumatic and hydraulic systems

*Pneumatic and hydraulic theory:*

Combined and ideal gas laws: Boyle's Law, Charles' Law and Gay-Lussac's Law

Fluid flow, calculation of pressure and velocity using Bernoulli's Equation for Newtonian fluids

System performance, volumetric operational and isothermal efficiency

Dynamic and Kinematic Viscosity

Methods of measuring viscosity including Stokes' Law

Navier Stokes Equations

### LO2 Identify the notation and symbols of pneumatic and hydraulic components

*Performance of hydraulic and pneumatic components:*

The use and importance of International Standards, including relative symbols and devices

Fluid power diagrams

Pneumatic and hydraulic critical equipment and their purpose

Circuit diagrams, component interaction and purpose

Dynamics of modern system use

### LO3 Examine the applications of pneumatic and hydraulic systems

*System applications:*

Calculation of appropriate capacities and specifications

Applied functions of control elements

Design and testing of hydraulic and pneumatic systems

Fluid power in real-life examples

Valued component choice

## LO4 Investigate the maintenance of pneumatic and hydraulic systems

### *Efficiency of systems:*

Efficient maintenance: accurate records and procedures to ensure efficiency

Functional inspection, modern techniques to limit production problems, quality control

Testing, efficient procedures to enable component longevity, recommendations

Fault finding, diagnostic techniques, effects of malfunctions, rectification of faults

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Calculate the parameters of pneumatic and hydraulic systems		<b>D1</b> Produce a presentation analysing fluid viscosity using Stokes' Law and validate how this relates to Navier-Stokes equations
<b>P1</b> Determine the change in volume and pressure in pneumatic systems <b>P2</b> Determine the change in volume and pressure in hydraulic systems	<b>M1</b> Using Bernoulli's Equation, calculate values at stationary incompressible flow	
<b>L02</b> Identify the notation and symbols of pneumatic and hydraulic components		<b>D2</b> Stating any assumptions, compare the applications of practical hydraulic and pneumatic systems
<b>P3</b> Identify the purpose of components on a given diagram <b>P4</b> Explain the use of logic functions used within circuits <b>P5</b> Illustrate the use of advanced functions and their effect on circuit performance	<b>M2</b> Assess the different factors that impact on actuator choice for a given application	

Pass	Merit	Distinction
<p><b>LO3</b> Examine the applications of pneumatic and hydraulic systems</p>		<p><b>D3</b> Evaluate the design modifications that can be introduced to improve the functionality and maintenance of pneumatic and hydraulic systems without creating reliability issues</p>
<p><b>P6</b> Investigate and analyse the design and function of a simple hydraulic or pneumatic system in a production environment</p> <p><b>P7</b> Define the purpose and function of electrical control elements in a given hydraulic or pneumatic system</p>	<p><b>M3</b> Justify the measures taken to improve circuit design in respect of performance</p>	
<p><b>LO4</b> Investigate the maintenance of pneumatic and hydraulic systems</p>		<p><b>D4</b> Evaluate the importance of maintenance, inspection, testing and fault finding in respect of improved system performance</p>
<p><b>P8</b> Recognise system faults and potential hazards in pneumatic and hydraulic systems</p> <p><b>P9</b> Determine regular testing procedures to ensure efficient maintenance of pneumatic and hydraulic systems</p>	<p><b>M4</b> Compare construction and operation of hydraulic and pneumatic systems with regards to legislation and safety issues</p>	



## Recommended Resources

### Textbooks

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

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

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

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

### Links

This unit links to the following related units:

*Unit 11: Fluid Mechanics*

*Unit 64: Thermofluids*

# Unit 30: Operations and Plant Management

<b>Unit code</b>	<b>R/615/1499</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

The challenges of modern manufacturing industries require today's operations engineers to adopt a multi-skilled methodology when dealing with the array of complex engineering problems they are faced with. Long gone are the days of 'pure' mechanical or electrical maintenance staff; operations engineers may well specialise within one discipline, but they must have the knowledge and ability to safely tackle problems that could encompass many varied engineering fields, if they are to keep the wheels of industry in motion.

The underlying aims of this unit are to develop the students' knowledge of the engineering fundamentals that augment the design and operation of plant engineering systems, and to furnish them with the tools and techniques to maintain the ever more technological equipment.

The students are introduced to the concept of thermodynamic systems and their properties in the first learning outcome; this will provide a platform for the topic of heat transfer in industrial applications (as covered in learning outcome four) and underpin their future studies in subsequent units. The second learning outcome examines common mechanical power transmission system elements found in numerous production/manufacturing environments, whilst the third learning outcome investigates fundamental static and dynamic fluid systems.

On completion of this unit students will be able to describe the fundamentals that underpin the operation of the systems they deal with on a daily basis and apply these fundamentals to the successful maintenance of these systems.

## **Learning Outcomes**

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

1. Analyse fundamental thermodynamic systems and their properties.
2. Investigate power transmission systems.
3. Determine the parameters of static and dynamic fluid systems
4. Examine the principles of heat transfer in industrial applications.

## Essential Content

### LO1 Analyse fundamental thermodynamic systems and their properties

#### *Fundamental system:*

Forms of energy and basic definitions

Definitions of systems (open and closed) and surroundings

First law of thermodynamics

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

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

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

### LO2 Investigate power transmission systems

#### *Power transmission:*

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

Constant wear and constant pressure theories

Gear trains: simple and compound gear trains; determination of velocity ratio; torque and power

Friction clutches: flat, single and multi-plate clutches; maximum power transmitted

Conical clutches: maximum power transmitted

### LO3 **Determine the parameters of static and dynamic fluid systems**

#### *Fluid flow theory:*

Continuity equations

Application of Bernoulli's Equation

Reynolds number; turbulent and laminar flow

Measuring devices for fluids: flow, viscosity and pressure

Determination of head loss in pipes by D'Arcy's formula, use of Moody diagrams

Immersed surfaces: centre of pressure, use of parallel axis theorem for immersed surfaces

Hydrostatic pressure and thrust on immersed surfaces

### LO4 **Examine the principles of heat transfer in industrial applications**

#### *Heat transfer:*

Modes of transmission of heat: conduction, convection and radiation

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

Recuperator, regenerator and evaporative heat exchangers

Application of formulae to heat exchangers

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Analyse fundamental thermodynamic systems and their properties		<b>D1</b> Illustrate the importance of expressions for work done in thermodynamic processes by applying first principles
<p><b>P1</b> Examine the operation of thermodynamic systems and their properties</p> <p><b>P2</b> Explain the application of the first law of thermodynamics to appropriate systems</p> <p><b>P3</b> Explain the relationships between system constants for a perfect gas</p>	<b>M1</b> Identify the index of compression in polytropic processes	
<b>LO2</b> Investigate power transmission systems		<b>D2</b> Compare the 'constant wear' and 'constant pressure' theories as applied to friction clutches
<p><b>P4</b> Calculate the maximum power which can be transmitted by means of a belt</p> <p><b>P5</b> Calculate the maximum power which can be transmitted by means of a friction clutch</p> <p><b>P6</b> Determine the power and torque transmitted through gear trains</p>	<b>M2</b> Discuss the factors that inform the design of an industrial belt drive system	

Pass	Merit	Distinction
<b>LO3</b> Determine the parameters of static and dynamic fluid systems		<b>D3</b> Compare the practical application of three different types of differential pressure measuring device
<b>P7</b> Determine the head losses in pipeline flow	<b>M3</b> Explore turbulent and laminar flow in Newtonian fluids	
<b>P8</b> Calculate the hydrostatic pressure and thrust on an immersed surface		
<b>P9</b> Determine the centre of pressure on an immersed surface		
<b>LO4</b> Examine the principles of heat transfer in industrial applications		<b>D4</b> Differentiate differences between parallel and counter flow recuperator heat exchangers
<b>P10</b> Determine the heat transfer through composite walls	<b>M4</b> Explore heat losses through lagged and unlagged pipes	
<b>P11</b> Apply heat transfer formulae to heat exchangers		

## Recommended resources

### Textbooks

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

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 29: Electro, Pneumatic and Hydraulic Systems*

*Unit 31: Electrical Systems and Fault Finding*



# Unit 31: Electrical Systems and Fault Finding

**Unit code** A/615/1500

**Unit level** 4

**Credit value** 15

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## Introduction

Electrical systems can be found in a very wide range of locations such as in manufacturing facilities, airports, transport systems, shopping centres, hotels and hospitals; people will come across them every day in their work place and at home. The system must take the electrical supply from the national grid, convert it to a suitable voltage and then distribute it safely to the various system components and uses such as electric motors, lighting circuits and environmental controls.

This unit introduces students to the characteristics and operational parameters of a range of electrical system components that are used in a variety of applications; and how to fault find when they go wrong.

On successful completion of this unit students will be able to follow electrical system circuit diagrams, understand the operation of the various components that make up the system and select the most suitable fault finding technique. Therefore, students will develop skills such as critical thinking, analysis, reasoning, interpretation, decision-making, information literacy, information and communication technology literacy, innovation, creativity, collaboration, and adaptability, which are crucial skills for gaining employment and developing academic competence for higher education progression.

## **Learning Outcomes**

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

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

## Essential Content

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

#### *Operating principles:*

Three-phase, single-phase distribution methods and connections

Earthing system connections

#### *Transformer constructional features:*

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

Electrical circuit symbols and layout diagrams

#### *Fault finding techniques and test equipment:*

Input/output, half split

Meters, insulation testers

Typical faults found

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

#### *Types and applications:*

Construction, application, characteristics, and testing

Types of electric motors and generators

Practical applications

Generation methods

Starting methods

Voltages, power, speed, torque, inertia

EMI, efficiency

Cooling and protection devices

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

*Types available and applications:*

Construction, application, characteristics and testing of lighting circuits

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

Practical applications

Voltages, energy usage, lumen output, efficiency, recycling

Safety requirements for use in hazardous zones

Heat and protection devices

*Lighting design:*

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

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

*Electrical safety standards:*

Approved codes of practice

*Component types available and applications:*

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Investigate the constructional features and applications of electrical distribution systems		<b>D1</b> Analyse the operation of single and three-phase techniques in electrical distribution systems
<b>P1</b> Describe the features of an electrical distribution system  <b>P2</b> Review the electrical component symbols used in circuit diagrams  <b>P3</b> Explain the different methods of single and three phase connections	<b>M1</b> Summarise the methods of safe fault finding on an electrical distribution system	
<b>L02</b> Examine the types and applications of electrical motors and generators		<b>D2</b> Justify the selection of a motor for a specific industrial application
<b>P4</b> Explain the types of electrical motors and generators available  <b>P5</b> Select suitable motors for various industrial applications  <b>P6</b> Review the different methods of starting induction motors and synchronous machines	<b>M2</b> Outline the efficiency of motors and generators	

Pass	Merit	Distinction
<b>L03</b> Analyse the types of lighting circuits available in the industry by assessing their practical application		<b>D3</b> Evaluate the practical application of a specific type of lighting circuit
<b>P7</b> Examine the types and construction of lighting devices  <b>P8</b> Explore a suitable lighting type for a specific application, considering its characteristics	<b>M3</b> Analyse the efficiency of lighting circuit designs	
<b>L04</b> Explain the operating characteristics of electrical safety components		<b>D4</b> Validate the selection of suitable electrical safety devices for a specific industrial application
<b>P9</b> Describe the operation, types and uses of electrical safety devices  <b>P10</b> List suitable safety components for a specific application	<b>M4</b> Determine the practical application of electrical safety devices in an industrial situation	

## Recommended Resources

### Textbooks

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 19: Electrical and Electronic Principles*

*Unit 21: Electrical Machines*

*Unit 22: Electronic Circuits and Devices*

## Unit 32:

# CAD for Maintenance Engineers

<b>Unit code</b>	<b>F/615/1501</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

There is a growing trend, in part due to the popularity of three-dimensional (3D) Computer Aided Design (CAD) systems, for students to generate two-dimensional (2D) drawings from three-dimensional (3D) solid models. 3D models do look impressive and whilst they clearly serve an important function in CAD design, in reality the vast majority of CAD drawings used in the industry are 2D based and, of those, a significant number are schematic drawings utilised by maintenance engineers, which cannot be produced using a 3D system.

The aim of this unit is to enable students to produce 2D CAD drawings (using industry standard CAD software), and to modify and construct electrical and mechanical drawings e.g. distribution systems, fire alarms, steam ranges, electrical and hydraulic circuits. This unit will support the development of the students' CAD abilities and build upon those skills to introduce the more advanced techniques that are used to create and modify schematic drawings quickly and efficiently. These techniques can be used to construct pre-prepared symbols for use in circuit diagrams, or be used to create unique symbols and symbol libraries.

Alongside the creation of schematic drawings utilising the block, attributes and insert commands, the students will also learn how to extract information to populate spreadsheets and databases, tabulating the information directly from the working drawing.



## **Learning Outcomes**

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

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

## Essential content

### LO1 Create and modify CAD drawings

*Introduction to the user interface:*

Command line, Status Bar, panel titles and tabs

Recognise and apply absolute, relative and polar coordinates

*Drafting aids:*

Grid, snap, object snap, ortho and polar tracking

*Draw commands:*

Linetypes, circle, text, hatching, dimensioning

*Modifying commands:*

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

Creating and defining text and dimension styles

*Creating layers:*

Layers/levels, colour

*Viewing commands:*

Zoom, pan, viewports and layouts

### LO2 Construct, insert and export blocks with textual attributes

Creating and editing blocks and write blocks

Defining, editing and managing attributes

Inserting blocks from external sources

Attribute extraction

Dynamic and nested blocks

Using the design centre and tool palettes

### LO3 **Produce complex schematic drawings**

Create block library and table legend, including symbols and description

Create electrical, electronic, hydraulic and pneumatic schematic drawings

### LO4 **Transfer information to external sources**

*Electronic transfer of information:*

Data extraction and data extraction (DXE) files

Extracting data to tables and spreadsheets

Organise and refine the extracted data

Table styles and formatting data extraction tables

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Create and modify CAD drawings		<b>D1</b> Evaluate the advantages of using template files
<p><b>P1</b> Identify the range of drawing aids that assist productivity</p> <p><b>P2</b> Produce a template file to include a range of layers, dimension styles, text styles, border and title box</p>	<p><b>M1</b> Contrast the advantages and disadvantages of using CAD over manual drafting</p>	
LO2 Construct, insert and export blocks with textual attributes		<b>LO2 &amp; LO3</b> <b>D2</b> Validate how using attributes can improve productivity
<p><b>P3</b> Create ten schematic symbols</p> <p><b>P4</b> Add appropriate attribute data to each of the schematic symbols and convert into blocks</p>	<p><b>M2</b> Identify the advantages of using blocks in a drawing</p>	
<b>LO3</b> Produce complex schematic drawings		
<p><b>P5</b> Produce a block library and table legend and integrate into a template file</p> <p><b>P6</b> Create a complex schematic drawing using electrical/electronic or hydraulic symbols</p>	<p><b>M3</b> Describe the advantages of using block libraries and how they can enhance templates</p>	

Pass	Merit	Distinction
<b>LO4</b> Transfer information to external sources		<b>D3</b> Assess how electronic transfer of information can aid productivity and provide example applications
<b>P7</b> Extract attribute data to Excel spreadsheets <b>P8</b> Explain the advantages of using data extraction (DXE) files	<b>M4</b> Appraise the process for extracting drawing data to create a table	

## Recommended Resources

### Textbooks

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

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

### Websites

<https://knowledge.autodesk.com> Autodesk Knowledge Network  
(Tutorials)

### Links

This unit links to the following related units:

*Unit 1: Engineering Design*

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

## Unit 34: Research Project

<b>Unit code</b>	<b>J/615/1502</b>
<b>Unit type</b>	<b>Core</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>30</b>

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### Introduction

Completing a piece of research is an opportunity for students to showcase their intellect and talents. It integrates knowledge with different skills and abilities that may not have been assessed previously, which may include seeking out and reviewing original research papers, designing their own experimental work, solving problems as they arise, managing time, finding new ways of analysing and presenting data, and writing an extensive report. Research can always be a challenge but one that can be immensely fulfilling, an experience that goes beyond a mark or a grade, but extends into long-lasting areas of personal and professional development.

This unit introduces students to the skills necessary to deliver a complex, independently conducted research project that fits within an engineering context.

On successful completion of this unit students will be able to deliver a complex and independent research project in line with the original objectives, explain the critical thinking skills associated with solving engineering problems, consider multiple perspectives in reaching a balanced and justifiable conclusion, and communicate effectively a research project's outcome. Therefore, students develop skills such as critical thinking, analysis, reasoning, interpretation, decision-making, information literacy, information and communication technology literacy, innovation, conflict resolution, creativity, collaboration, adaptability and written and oral communication.

## **Learning Outcomes**

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

1. Conduct the preliminary stages involved in the creation of an engineering research project.
2. Examine the analytical techniques used to work on all stages of the project and strategies required to overcome the challenges involved in a research project.
3. Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering context.
4. Explore the communication approach used for the preparation and presentation of the research project's outcomes.



## Essential Content

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

*Setting up the research preliminaries:*

Project proposal

Developing a research question(s)

Selection of project approach

Identification of project supervisor

Estimation of resource requirements, including possible sources of funding

Identification of project key objectives, goals and rationale

Development of project specification

### LO2 **Examine the analytical techniques used to work on all stages of the project and strategies required to overcome the challenges involved in a research project**

*Investigative skills and project strategies:*

Selecting the method(s) of collecting data

Data analysis and interpreting findings

Literature review

Engaging with technical literature

Technical depth

Multi-perspectives analysis

Independent thinking

Statement of resources required for project completion

Potential risk issues, including health and safety, environmental and commercial

Project management and key milestones

**LO3 Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering context**

*Research purpose:*

Detailed statement of project aims

Relevance of the research

Benefits and beneficiaries of the research

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

*Reporting the research:*

Project written presentation

Preparation of a final project report

Writing research report

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

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Conduct the preliminary stages involved in the creation of an engineering research project		<b>D1</b> Produce a comprehensive project proposal that evaluates and justifies the rationale for the research
<p><b>P1</b> Produce a research project proposal that clearly defines a research question or hypothesis</p> <p><b>P2</b> Discuss the key project objectives, the resulting goals and rationale</p>	<b>M1</b> Analyse the project specification and identify any project risks	
<b>LO2</b> Examine the analytical techniques used to work on all stages of the project and strategies required to overcome the challenges involved in a research project		<b>D2</b> Critically analyse literature sources utilised, data analysis conducted and strategies to deal with challenges
<p><b>P3</b> Conduct a literature review of published material, either in hard copy or electronically, that is relevant to your research project</p> <p><b>P4</b> Examine appropriate research methods and approaches to primary and secondary research</p>	<p><b>M2</b> Analyse the strategies used to overcome the challenges involved in the literature review stage</p> <p><b>M3</b> Discuss merits, limitations and pitfalls of approaches to data collection and analysis</p>	

Pass	Merit	Distinction
<b>L03</b> Reflect on the impact the research experience could have in enhancing personal or group performance within an engineering context		<b>D3</b> Critically evaluate how the research experience enhances personal or group performance within an engineering context
<b>P5</b> Reflect on the effectiveness and the impact the experience has had upon enhancing personal or group performance	<b>M4</b> Evaluate the benefits from the findings of the research conducted	
<b>L04</b> Explore the communications approach used for the preparation and presentation of the research project's outcomes		<b>D4</b> Critically reflect how the audience for whom the research was conducted influenced the communication approach used for the preparation and presentation of the research project's outcomes
<p><b>P6</b> Explore the different types of communications approaches that can be used to present the research outcomes</p> <p><b>P7</b> Communicate research outcomes in an appropriate manner for the intended audience</p>	<b>M5</b> Evaluate how the communication approach meets research project outcomes and objectives	

## Recommended Resources

### Textbooks

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

Apple Academic Press Inc.

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

### Websites

<https://www.apm.org.uk/>

Association for Project Management  
(General Reference)

# Unit 35: Professional Engineering Management

<b>Unit code</b>	<b>L/615/1503</b>
<b>Unit type</b>	<b>Core</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Engineers are professionals who can design, develop, manufacture, construct, operate and maintain the physical infrastructure and content of the world we live in. They do this by using their academic knowledge and practical experience, in a safe, effective and sustainable manner, even when faced with a high degree of technical complexity.

The aim of this unit is to continue building up on the knowledge gained in *Unit 4: Managing a Professional Engineering Project*, to provide students with the professional standards for engineers and to guide them on how to develop the range of employability skills needed by professional engineers.

Among the topics included in this unit are: engineering strategy and services delivery planning, the role of sustainability, Total Quality Management (TQM), engineering management tools, managing people and becoming a professional engineer.

On successful completion of this unit students will be able to construct a coherent engineering services delivery plan to meet the requirements of a sector-specific organisation or business. They will display personal commitment to professional standards and obligations to society, the engineering profession and the environment.

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

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

## **Learning Outcomes**

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

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

## Essential Content

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

*The engineering business environment:*

Organisational structures and functional elements

Strategic planning and deployment

Engineering strategy and services delivery planning

The role of sustainability

Total Quality Management (TQM)

Logistics and supply chain management

New product development strategies

Legal obligations and corporate responsibility

*Engineering relationships:*

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

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

*Engineering management tools:*

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



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

#### *Managing people:*

Describe the most effective leadership styles

Techniques to effectively manage teams

#### *Steps to follow for delivering effective presentations.*

Meeting management skills

Communication and listening skills

Negotiating skills

Human error evaluation

Coaching and mentoring

### **LO4 Develop personal commitment to professional standards and obligations to society, the engineering profession and the environment**

#### *Becoming a professional engineer:*

Engineering social responsibility

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

Methods of Continuing Professional Development (CPD)

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<p><b>LO1</b> Evaluate the risk evaluation theories and practices associated with the management of projects for the production of current and developing technology</p>		<p><b>D1</b> Specify and analyse the challenges encountered when meeting the requirements for successfully managing engineering activities, and make justified recommendations to overcome these challenges</p>
<p><b>P1</b> Evaluate the risk evaluation theories and practices associated with the management of engineering projects</p> <p><b>P2</b> Assess elements and issues that impact the successful management of engineering activities</p>	<p><b>M1</b> Critically evaluate the main elements and issues that impact the successful management of engineering activities</p>	
<p><b>LO2</b> Produce an engineering services delivery plan that meets the requirements of a sector-specific organisation</p>		<p><b>D2</b> Critically evaluate contingencies that might prevent the delivery plan meeting the requirements of a sector-specific organisation</p>
<p><b>P3</b> Develop an engineering services delivery plan, applying the appropriate sector-specific requirements</p> <p><b>P4</b> Determine the engineering management tools needed for designing an engineering services delivery plan</p>	<p><b>M2</b> Evaluate how each step of the delivery plan developed meets the requirements of a sector specific organisation</p>	

Pass	Merit	Distinction
<b>LO3</b> Develop effective leadership, individual and group communication skills		<b>D3</b> Critically evaluate effective ways for the coaching and mentoring of disillusioned colleagues or of a poorly performing team
<b>P5</b> Describe the steps for effective persuasion and negotiation  <b>P6</b> Explain the steps for managing effective group meetings  <b>P7</b> Outline the steps to deliver an effective presentation	<b>M3</b> Evaluate leadership styles and effective communication skills using specific examples in an organisational context	
<b>LO4</b> Develop personal commitment to professional standards and obligations to society, the engineering profession and the environment		<b>D4</b> Evaluate and provide justifications on why it is necessary to be active and up to date with the engineering profession's new developments and discoveries
<b>P8</b> Discuss the context of social responsibility for scientists and engineers  <b>P9</b> Explore the ways in which an engineer can engage in continuing professional development	<b>M4</b> Summarise the engineering profession ethical standards and patterns of behaviour	

## Recommended Resources

### Textbooks

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

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

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

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

### Websites

<http://www.engc.org.uk/>      Engineering Council  
UK-SPEC UK Standard for Professional Engineering  
Competence  
(E-Books)

<http://www.ewb-uk.org/>      Engineering without Borders  
(General Reference)

### Links

This unit links to the following related units:

*Unit 4: Managing a Professional Engineering Project*

# Unit 36: Advanced Mechanical Principles

<b>Unit code</b>	<b>R/615/1504</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

A mechanical engineer is required to have an advanced knowledge of most of the machinery used within the engineering industry, and should understand the physical laws that influence their operation.

The aim of this unit is to continue covering the topics discussed in *Unit 9: Mechanical Principles*. It will provide students with advanced knowledge of the mechanical theories associated with engineering applications.

Topics included in this unit are: Poisson's Ratio and typical values of common materials; the relationship between the elastic constants such as Bulk Modulus, Modulus of Elasticity, Modulus of Rigidity; the relationship between bending moment, slope and deflection in beams; calculating the slope and deflection for loaded beams using Macaulay's method; analysing the stresses in thin-walled pressure vessels; and stresses in thick-walled cylinders, flat and v-section belt drive theory.

On successful completion of this unit students will be able to have more advanced knowledge of mechanical principles to determine the behavioural characteristics of materials subjected to complex loading; assess the strength of loaded beams and pressurised vessels; determine specifications of power transmission system elements; and examine operational constraints of dynamic rotating systems.

## Learning Outcomes

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

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

## Essential Content

### LO1 Determine the behavioural characteristics of materials subjected to complex loading

#### *Characteristics of materials:*

Definition of Poisson's Ratio and typical values of metals, plastics and composite materials

The relationship between the elastic constants such as Bulk Modulus, Modulus of Elasticity, Modulus of Rigidity and Poisson's Ratio

Characteristics of two-dimensional and three-dimensional loading

Calculation of volumetric strain and volume changes

### LO2 Assess the strength of loaded beams and pressurised vessels

#### *Strength:*

The relationship between bending moment, slope and deflection in beams

Calculating the slope and deflection for loaded beams using Macaulay's method

Analysing the stresses in thin-walled pressure vessels and stresses in thick-walled cylinders

### LO3 Analyse the specifications of power transmission system elements

#### *Specifications:*

Flat and v-section belt drive theory

Operation of friction clutches with uniform pressure and uniform wear theories

Principles of both epicyclic and differential gearing, and the torque required to accelerate these systems

Areas of failure when transmitting power mechanically

#### LO4 **Examine operational constraints of dynamic rotating systems**

*Operational constraints:*

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

Operating principles of flywheels to store mechanical energy

Balancing of rotating mass systems

The effects of coupling on freely rotating systems

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Determine the behavioural characteristics of materials subjected to complex loading		<b>D1</b> Critique the behavioural characteristics of materials subjected to complex loading
<p><b>P1</b> Discuss the relationship between the elastic constants</p> <p><b>P2</b> Illustrate the effects of two-dimensional and three-dimensional loading on the dimensions of a given material</p> <p><b>P3</b> Determine the volumetric strain and change in volume due to three-dimensional loading</p>	<p><b>M1</b> Assess the effects of volumetric thermal expansion and contraction on isotropic materials</p>	
<b>L02</b> Assess the strength of loaded beams and pressurised vessels		<b>D2</b> Critique and justify your choice of suitable size universal beam using appropriate computer software to model the application by explaining any assumptions that could affect the selection
<p><b>P4</b> Evaluate the variation of slope and deflection along a simply supported beam</p> <p><b>P5</b> Determine the principal stresses that occur in a thin walled cylindrical pressure vessel and a pressurised thick-walled cylinder</p>	<p><b>M2</b> Review a suitable size universal beam from appropriate data tables which conforms to given design specifications for slope and deflection</p>	



Pass	Merit	Distinction
<p><b>L03</b> Analyse the specifications of power transmission system elements</p>		<p><b>D3</b> Evaluate the conditions needed for an epicyclic gear train to become a differential, and show how a differential works in this application</p>
<p><b>P6</b> Discuss the initial tension requirements for the operation of a v-belt drive</p> <p><b>P7</b> Analyse the force requirements to engage a friction clutch in a mechanical system</p> <p><b>P8</b> Analyse the holding torque and power transmitted through epicyclic gear trains</p>	<p><b>M3</b> Critically analyse both the uniform wear and uniform pressure theories of friction clutches for their effectiveness in theoretical calculations</p>	
<p><b>L04</b> Examine operational constraints of dynamic rotating systems</p>		<p><b>D4</b> Critically evaluate and justify the different choices of cam follower that could be selected to achieve a specified motion, explaining the advantages and disadvantages of each application</p>
<p><b>P9</b> Explore the profiles of both radial plate and cylindrical cams that will achieve a specified motion</p> <p><b>P10</b> Show the mass of a flywheel needed to keep a machine speed within specified limits</p> <p><b>P11</b> Investigate the balancing masses required to obtain dynamic equilibrium in a rotating system</p>	<p><b>M4</b> Evaluate the effects of misalignment of shafts and the measures that are taken to prevent problems from occurring</p>	

## Recommended Resources

### Textbooks

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

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 8: Mechanical Principles*

## Unit 37:

## Virtual Engineering

<b>Unit</b>	<b>Y/615/1505</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

The work of an engineer increasingly involves the use of powerful software modelling tools (virtual modelling). These tools allow us to predict potential manufacturing difficulties, suggest how a product or component is likely to behave in service, and undertake rapid and low cost design iteration and optimisation, to reduce costs, pre-empt failure and enhance performance.

This unit introduces students to the application of relevant Computer Aided Design (CAD) and analysis engineering tools in contemporary engineering. They will learn about standards, regulations and legal compliance within the context of engineering.

Topics included in this unit are: dimensioning and tolerances, standardisation and regulatory compliance (BS, ASTM, ISO, etc.), material properties and selection, manufacturing processes, 2D, 3D, CAD, solid modelling, one-dimensional and multi-dimensional problems, meshing and boundary conditions, and the finite volume method.

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

## Learning Outcomes

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

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

## Essential Content

### LO1 **Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering**

*Engineering design fundamentals:*

Dimensioning and tolerances

Standardisation and regulatory compliance (BS, ASTM, ISO, etc.)

*How to manufacture and what to manufacture:*

Material properties and selection

Manufacturing processes: capability, cost issues and selection

*Design tools:*

2D and 3D CAD

Solid modelling

File types, export and compatibility

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

Results obtained, comparison of data, benefits and limitations

Generalisation of provided information, recommendations on current and future applications

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

*Finite element formulation:*

One-dimensional problems

Multi-dimensional problems

Beams

*Finite element method:*

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

Define material properties and boundary conditions; choose appropriate functions, formulate equations, solve equations, visualise and explain the results

**LO3 Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting**

*Fundamentals of CFD (Computational Fluid Dynamics):*

CFD and the finite volume method background

Meshing and boundary conditions

Applications, advantages and limitations of CFD

*CFD simulation and analysis:*

Apply CFD to simple design/aerodynamics problems: define the problem, provide initial boundary conditions for the problem, set-up a physical model, define material properties and operating conditions

Interpretation of CFD results

Examine the solution using graphical and numerical tools; suggest and make revision of the models

**LO4 Determine faults in the application of simulation techniques to evaluate the modelling method and data accuracy**

*Simulation results:*

Extracting relevant information from simulation-based exercises

Interpretation and presentation of results through a series of guided exercises

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering		<b>D1</b> Critically evaluate and provide supported recommendations for the application of computer-based models to an industrial environment that would improve efficiency and problem-solving
<b>P1</b> Discuss the benefits and pitfalls of computer based models used within an industrial environment to solve problems in engineering	<b>M1</b> Evaluate the capabilities and limitations of computer-based models  <b>M2</b> Evaluate the processes and applications used in solving problems in engineering	
<b>LO2</b> Analyse finite element product and system models in order to find and solve potential structural or performance issues		<b>D2</b> For a range of practical examples, provide supported and justified recommendations for recognising and solving potential structural or performance-based issues, using finite element product and systems models
<b>P2</b> Analyse the role of finite element analysis in modelling products and systems  <b>P3</b> Review a range of practical examples to solve potential structural or performance-based issues using finite element product and systems models	<b>M3</b> Critically analyse the finite element product and systems models that help to find and solve potential performance or structural issues for a range of practical examples	

Pass	Merit	Distinction
<b>L03</b> Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting		<b>D3</b> Provide supported and appropriate recommendations for improving efficiency and the generation of suitable meshes for CFD simulations
<b>P4</b> Demonstrate the importance of CFD simulations applied to evaluate pressure and velocity distributions in the engineering setting  <b>P5</b> Complete CFD simulation to evaluate pressure and velocity distributions within an engineering setting	<b>M4</b> Evaluate the application and limitations of CFD in an engineering context	
<b>L04</b> Determine faults in the application of simulation techniques to evaluate the modelling method and data accuracy		<b>D4</b> Critically evaluate the appropriate application of simulation techniques that can support decision-making
<b>P6</b> Determine the faults in the application of simulation techniques  <b>P7</b> Discuss and evaluate the modelling method and data accuracy	<b>M5</b> Extract relevant information from simulation  <b>M6</b> Trace potential faults in the application of simulation techniques  <b>M7</b> Critically review results through a series of guided exercises and recommendations	



## Recommended Resources

### Textbooks

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

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 1: Engineering Design*

*Unit 50: Advanced Manufacturing Technology*

# Unit 38: Further Thermodynamics

<b>Unit code</b>	<b>D/615/1506</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

From the refrigerators that we use in our homes to the colossal power stations that generate the electricity we use and provide power to industry, the significance that thermodynamics plays in the 21st century cannot be underestimated.

The aim of this unit is to build on the techniques explored in *Unit 13: Fundamentals of Thermodynamics and Heat Engines*, to develop further students' skills in applied thermodynamics by investigating the relationships between theory and practice.

Among the topics included in this unit are: heat pumps and refrigeration, performance of air compressors, steam power plant and gas turbines.

On successful completion of this unit students will be able to determine the performance and operation of heat pumps and refrigeration systems, review the applications and efficiency of industrial compressors, use charts and/or tables to determine steam plant parameters and characteristics, describe the operation of gas turbines and assess their efficiency.

## Learning Outcomes

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

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

## Essential Content

### LO1 Evaluate the performance and operation of heat pumps and refrigeration systems

*Heat pumps and refrigeration:*

Reversed heat engines: reversed Carnot and Rankine cycles

Second law of thermodynamics

Refrigeration tables and charts (p-h diagrams)

Coefficient of performance of heat pumps and refrigerators

Refrigerant fluids: properties and environmental effects

Economics of heat pumps

### LO2 Review the applications and efficiency of industrial compressors

*Performance of air compressors:*

Theoretical and realistic cycles

Isothermal and adiabatic work

Volumetric efficiency

Intercoolers, dryers and air receivers

Hazards and faults: safety consideration and associated legislation

### LO3 Determine steam plant parameters and characteristics, using charts and/or tables

*Steam power plant:*

Use of tables and charts to analyse steam cycles

Circuit diagrams showing boiler, super heater, turbine, condenser and feed pump

Theoretical and actual operation: Carnot and Rankine cycle

Efficiencies and improvements

## LO4 Examine the operation of gas turbines and assess their efficiency

### *Gas turbines:*

Single and double shaft gas turbine operation

Property diagrams: Brayton (Joule) cycle

Intercooling, reheat and regeneration

Combined heat and power plants

Self-starting and burner ignition continuation

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Evaluate the performance and operation of heat pumps and refrigeration systems		<b>D1</b> Conduct a cost-benefit analysis on the installation of a ground source heat pump on a smallholding to make valid recommendations for improvements
<p><b>P1</b> Using didactic sketches, evaluate the operating principles of both heat pumps and refrigeration systems</p> <p><b>P2</b> Use refrigeration tables and pressure/enthalpy charts to determine COP, heating effect and refrigeration effect of reversed heat engines</p>	<p><b>M1</b> Assess the limiting factors that impact on the economics of heat pumps</p> <p><b>M2</b> Illustrate the contradiction between refrigeration cycles and the second law of thermodynamics</p>	
<b>L02</b> Review the applications and efficiency of industrial compressors		<b>D2</b> Critically evaluate volumetric efficiency formula for a reciprocating compressor
<p><b>P3</b> Assess the different types of industrial compressor and identify justifiable applications for each</p> <p><b>P4</b> Discuss compressor faults and potential hazards</p> <p><b>P5</b> Determine the volumetric efficiency of a reciprocating compressor</p>	<b>M3</b> Evaluate isothermal efficiency by calculating the isothermal and polytropic work of a reciprocating compressor	

Pass	Merit	Distinction
<b>L03</b> Determine steam plant parameters and characteristics using charts and/or tables		<b>D3</b> Critically evaluate the pragmatic modifications made to the basic Rankine cycle to improve the overall efficiency of steam generation power plants
<b>P6</b> Discuss the need for superheated steam in a power generating plant  <b>P7</b> Apply the use of charts and/or tables to establish overall steam plant efficiencies in power systems	<b>M4</b> Justify why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world	
<b>L04</b> Examine the operation of gas turbines and assess their efficiency		<b>D4</b> Critically analyse the practical solutions manufacturers offer to overcome problematic areas in gas turbines, such as burner ignition continuation and self-starting capabilities
<b>P8</b> Investigate the principles of operation of a gas turbine plant  <b>P9</b> Assess the efficiency of a gas turbine system	<b>M5</b> Compare and evaluate the actual plant and theoretical efficiencies in a single shaft gas turbine system, accounting for any discrepancies found	

## Recommended Resources

### Textbooks

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

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

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

### Websites

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

### Links

This unit links to the following related units:

*Unit 13: Fundamentals of Thermodynamics and Heat Engines*

## Unit 39:

## Further Mathematics

<b>Unit code</b>	<b>H/615/1507</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

The understanding of more advanced mathematics is important within an engineering curriculum to support and broaden abilities within the applied subjects at the core of all engineering programmes. Students are introduced to additional topics that will be relevant to them as they progress to the next level of their studies, advancing their knowledge of the underpinning mathematics gained in *Unit 2: Engineering Maths*.

The unit will prepare students to analyse and model engineering situations using mathematical techniques. Among the topics included in this unit are: number theory, complex numbers, matrix theory, linear equations, numerical integration, numerical differentiation, and graphical representations of curves for estimation within an engineering context. Finally, students will expand their knowledge of calculus to discover how to model and solve engineering problems using first and second order differential equations.

On successful completion of this unit students will be able to use applications of number theory in practical engineering situations, solve systems of linear equations relevant to engineering applications using matrix methods, approximate solutions of contextualised examples with graphical and numerical methods, and review models of engineering systems using ordinary differential equations.



## **Learning Outcomes**

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

1. Use applications of number theory in practical engineering situations.
2. Solve systems of linear equations relevant to engineering applications using matrix methods.
3. Approximate solutions of contextualised examples with graphical and numerical methods.
4. Review models of engineering systems using ordinary differential equations.

## Essential Content

### LO1 Use applications of number theory in practical engineering situations

#### *Number theory:*

Bases of a number (Denary, Binary, Octal, Duodecimal, Hexadecimal) and converting between bases

Types of numbers (Natural, Integer, Rational, Real, Complex)

The modulus, argument and conjugate of complex numbers

Polar and exponential forms of complex numbers

The use of de Moivre's Theorem in engineering

Complex number applications e.g. electric circuit analysis, information and energy control systems

### LO2 Solve systems of linear equations relevant to engineering applications using matrix methods

#### *Matrix methods:*

Introduction to matrices and matrix notation

The process for addition, subtraction and multiplication of matrices

Introducing the determinant of a matrix and calculating the determinant for a 2x2 and 3x3 matrix

Using the inverse of a square matrix to solve linear equations

Gaussian elimination to solve systems of linear equations (up to 3x3)

### LO3 **Approximate solutions of contextualised examples with graphical and numerical methods**

*Graphical and numerical methods:*

Standard curves of common functions, including quadratic, cubic, logarithm and exponential curves

Systematic curve sketching knowing the equation of the curve

Using sketches to approximate solutions of equations

Numerical analysis using the bisection method and the Newton–Raphson method

Numerical integration using the mid-ordinate rule, the trapezium rule and Simpson’s rule

### LO4 **Review models of engineering systems using ordinary differential equations**

*Differential equations:*

Formation and solutions of first-order differential equations

Applications of first-order differential equations e.g. RC and RL electric circuits, Newton’s laws of cooling, charge and discharge of electrical capacitors and complex stresses and strains

Formation and solutions of second-order differential equations

Applications of second-order differential equations e.g. mass-spring-damper systems, information and energy control systems, heat transfer, automatic control systems and beam theory and RLC circuits

Introduction to Laplace transforms for solving linear ordinary differential equations

Applications involving Laplace transforms such as electric circuit theory, load frequency control, harmonic vibrations of beams, and engine governors

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Use applications of number theory in practical engineering situations		<b>D1</b> Test the correctness of a trigonometric identity using de Moivre's Theorem
<p><b>P1</b> Apply addition and multiplication methods to numbers that are expressed in different base systems</p> <p><b>P2</b> Solve engineering problems using complex number theory</p> <p><b>P3</b> Perform arithmetic operations using the polar and exponential form of complex numbers</p>	<b>M1</b> Solve problems using de Moivre's Theorem	
<b>L02</b> Solve systems of linear equations relevant to engineering applications using matrix methods		<b>D2</b> Validate solutions for the given engineering linear equations using appropriate computer software
<p><b>P4</b> Calculate the determinant of a set of given linear equations using a 3x3 matrix</p> <p><b>P5</b> Solve a system of three linear equations using Gaussian elimination</p>	<b>M2</b> Determine the solution to a set of given engineering linear equations using the Inverse Matrix Method for a 3x3 matrix	

Pass	Merit	Distinction
<b>L03</b> Approximate solutions of contextualised examples with graphical and numerical methods		<b>D3</b> Critically evaluate the use of numerical estimation methods, commenting on their applicability and the accuracy of the methods
<p><b>P6</b> Estimate solutions of sketched functions using a graphical estimation method</p> <p><b>P7</b> Calculate the roots of an equation using two different iterative techniques</p> <p><b>P8</b> Determine the numerical integral of engineering functions using two different methods</p>	<b>M3</b> Solve engineering problems and formulate mathematical models using graphical and numerical integration	
<b>L04</b> Review models of engineering systems using ordinary differential equations		<b>D4</b> Critically evaluate first and second-order differential equations when generating the solutions to engineering situations using models of engineering systems
<p><b>P9</b> Formulate and solve first order differential equations related to engineering systems</p> <p><b>P10</b> Formulate and solve second order homogeneous and non-homogeneous differential equations related to engineering systems</p> <p><b>P11</b> Calculate solutions to linear ordinary differential equations using Laplace transforms</p>	<b>M4</b> Demonstrate how different models of engineering systems using first-order differential equations can be used to solve engineering problems	

## Recommended Resources

### Textbooks

BIRD, J. (2014) *Higher Engineering Mathematics*. 7th Ed. London: Routledge.

SINGH, K. (2011) *Engineering Mathematics Trough Applications*. Basingstoke, Palgrave Macmillan.

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

### Journals

*Communications on Pure and Applied Mathematics*. Wiley.

*Journal of Engineering Mathematics*. Springer.

*Journal of Mathematical Physics*. American Institute of Physics.

### Websites

<http://www.mathcentre.ac.uk/> Maths Centre  
(Tutorials)

<http://www.mathtutor.ac.uk/> Maths Tutor  
(Tutorials)

### Links

This unit links to the following related unit:

*Unit 2: Engineering Maths*

# Unit 40: Commercial Programming Software

**Unit code** K/615/1508

**Unit level** 5

**Credit value** 15

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## Introduction

The use of Computer Aided Design (CAD) and simulation in the electronic and electrical engineering industry is ever growing. Commercial software packages enable an engineer to design, simulate, model and predict the outcome of a design before a product has been made. This enables time and cost savings in the development of a product whilst enabling the engineer to further develop their design.

The aim of this unit is to introduce students to the availability and use of commercial software packages within electronics engineering, including design, simulation, simple microprocessor programming and evaluation of the tools available.

On successful completion of this unit students will be able to research a range of software tools or applications to support engineering functions related to electronics, consider how a software package can be used to simulate the behaviour of an electronic circuits function, explain how to programme a microprocessor-based device to achieve a specified outcome/task, evaluate a specific electronics software tool/application, describe the types of commercial software available, compare the differences between a software simulation and a real-world circuit, and write simple commands to a microcontroller.

## Learning Outcomes

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

1. Research a range of software application tools to determine how they can support electronic engineering functions effectively.
2. Explain how a software package can be used to simulate the behaviour of an electronic circuit function and compare the results to real components and circuits.
3. Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software.
4. Evaluate an electronics software application tool to report on its ability to replicate the real world and the resource savings this can bring to an organisation.



## Essential Content

### LO1 **Research a range of software application tools to determine how they can support electronic engineering functions effectively**

*Exposition of computer packages or applications:*

Circuit design, simulation, testing and analysis

Printed circuit board layouts

Electronic design automation (EDA or ECAD)

Microcontroller programming, such as Programmable Intelligent Computers (PICs). Microcontroller function simulation, monitoring and testing

### LO2 **Explain how a software package can be used to simulate the behaviour of an electronic circuit function and compare the results to real components or circuits**

*Application of an industrial computer-aided design package:*

Simulation and analysis of electronic circuits

*PCB design:*

Creation of schematic netlists of a given design and transfer to a PCB layout to make design created using computer-based tools

*Build:*

Component identification and handling

Develop soldering skills to be able to populate a printed circuit board

*Test and comparison:*

Application of test equipment to measure voltage, current and resistance

Systematic test, commission and fault finding methods

Compare simulated values with tested values, comparison criteria to include; function, behaviour, accuracy, response times and errors

**LO3 Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software**

*Introduction to microprocessors:*

Introduction to: common languages, compilers and simulators in-circuit debugging

simple programming for exercises:

Digital inputs, simple user feedback

Simulation and debugging

Motor, relay and sound outputs

Communication

**LO4 Review an electronics software application tool to report on its ability to replicate the real world and the resource savings this can bring to an organisation**

*Software application:*

Software applications with specific industry examples incorporating ease of use, functions available, performance, reliability, quality and costs

Possible limiting factors in software systems, based on previous work undertaken in the unit

Current trends in simulation, testing and microprocessor development

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Research a range of software application tools to determine how they can support electronic engineering functions effectively		<b>D1</b> Evaluate the functions and benefits of a range of commercial software used in developing electrical engineering
<b>P1</b> Examine the functions of commercial programming software  <b>P2</b> Discuss the categories of commercial electrical and electronic software	<b>M1</b> Analyse the effectiveness of a range of commercial software in supporting electronic engineering functions	
<b>L02</b> Explain how a software package can be used to simulate the behaviour of an electronic circuit function and compare the results to real components or circuits		<b>D2</b> Critically evaluate the functionality of simulation in comparison to real components using a complex PCB layout
<b>P3</b> Design a simple PCB layout using a software package  <b>P4</b> Investigate and compare results produced in simulation to develop an analysis with the physical build	<b>M2</b> Design a complex PCB layout with a good level of optimisation using a software package  <b>M3</b> Evaluate functionality of simulation to show considered comparisons between testing and simulation	

Pass		Merit	Distinction
<b>L03</b> Programme a microprocessor-based device to achieve a specified outcome or task using commercially available software			<b>D3</b> Critically evaluate the functionality of simulation by noting variations between testing and simulation
<b>P5</b> Programme a microprocessor-based device to produce working code using appropriate software	<b>M4</b> Make improvements to given examples to produce complex working code	<b>M5</b> Evaluate code through simulation and in the hardware, demonstrating good competence of the software	
<b>P6</b> Test and review code used through simulation and in the hardware			
<b>L04</b> Review an electronics software application tool to report on its ability to replicate the real world and the resource savings this can bring to an organisation			<b>D4</b> Critically analyse current and emerging applications of commercial software with clear application to industry examples, identifying trends and recognising technical and economic factors which influence developments
<b>P7</b> Evaluate an electronics software application and its ability to replicate the real world, supported by industry specific examples and illustrating the resource savings implications offered by this approach	<b>M6</b> Analyse an electronics software application and its ability to replicate the real world, supported by specific industry examples and illustrating the resource savings implications this has		

## Recommended Resources

### Textbooks

BLUM, J. (2013) *Exploring Arduino*. Wiley.

PETRUZZELLIS, T. (2005) *Build your own electronics workshop*. McGraw-Hill.

ROBBINS, A. and MILLER, W.C. (2013) *Circuit analysis: theory and practice*. 5th Ed. International Ed. Clifton Park, N.Y.: Delmar.

RICHARDSON, M. and WALLACE, S. (2013) *Getting started with Raspberry Pi*. 1st Ed. Maker Media Inc.

### Websites

<https://www.circuitlab.com/>      Circuit Lab  
Online schematic editor and circuit simulator  
(Training)

### Links

This unit links to the following related units:

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

*Unit 37: Virtual Engineering*

*Unit 41: Distributed Control Systems*

# Unit 41: Distributed Control Systems

<b>Unit code</b>	<b>M/615/1509</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

With increased complexity and greater emphasis on cost control and environmental issues, the efficient control of manufacture and processing plant becomes ever more important. While small and medium scale industries require Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) technologies, large scale applications require Distributed Control Systems (DCS).

This unit introduces students to the applications of Distributed Control Systems in industrial measurements and control engineering, the different types of industrial networking used in control and instrumentation, the analysis of the performance of a given control system, and how to suggest appropriate solutions using a variety of possible methods.

On successful completion of this unit students will be able to explain the impact of automated systems in modern control processes, explain the basic concepts, architecture, operation and communication of distributed control systems, identify appropriate techniques to specify and implement a simple DCS and develop programmes to use machine interfaces to monitor and control the behaviour of a complex system.

## Learning Outcomes

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

1. Explore the impact of automated systems in modern control processes.
2. Evaluate the basic concepts, architecture, operation and communication of Distributed Control Systems.
3. Suggest appropriate techniques to specify and implement a simple Distributed Control System.
4. Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system.

## Essential Content

### LO1 Explore the impact of automated systems in modern control processes

#### *Modern control processes:*

Introduction to computer-based control systems and typical distributed control systems

An overview of DCS and SCADA systems

Fundamentals of PLC

Comparison of DCS, SCADA and PLCs

Selection and justification of control strategies

### LO2 Evaluate the basic concepts, architecture, operation and communication of Distributed Control Systems

#### *Distributed Control Systems:*

Evolution and description of commercial DCS, DCS elements

Basic DCS controller configuration

Introduction to basic communication principles and protocol for DCS, PLC and SCADA

Hierarchical systems and distributed systems

Introduction to simulation models and packages

### LO3 Suggest appropriate techniques to specify and implement a simple Distributed Control System

#### *Techniques:*

Introduction to programmable controllers, programming of PLC and DCS systems

Operator interface

Alarm system management for DCS systems

Distributed Control System reporting

Configuration of hardware and software of PLC and DCS

Programmable controller interfacing and troubleshooting

Configuration of a typical DCS control using typical plant problems

**LO4 Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system**

*Behaviours:*

Computation of control systems

Control and supervision of Distributed Control Systems

Human Machine Interfaces (HMIs) and alarms

Network communication standards

Application of field interfaces and networks

Application of diagnostic and maintenance consideration

Project implementation phases and life cycle

Overview of future trends (e.g. digital control, intelligent systems and virtual instruments)



## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Explore the impact of automated systems in modern control processes		<b>D1</b> Critically evaluate and justify the selection of the control strategies and their function against the specifications of a DCS
<b>P1</b> Discuss the application of DCS, SCADA and PLC, and their respective fields of application  <b>P2</b> Investigate the component parts and their respective functions, in a modern control process  <b>P3</b> Review the main building blocks (layout), communication paths and signal level(s) of a DCS	<b>M1</b> Evaluate the use of DCS from field devices to commercial data processing  <b>M2</b> Illustrate the control modes, structures, and diagnostic methods used in controllers	
<b>LO2</b> Evaluate the basic concepts, architecture, operation and communication of Distributed Control Systems		
<b>P4</b> Evaluate the concept, architecture, operation and communication of DCS, SCADA and PLC in their respective applications  <b>P5</b> Review the hierarchical systems in DCS  <b>P6</b> Assess the use of Local Area Network, field bus types, and protocols	<b>M3</b> Critique the input output interface, fieldbus protocols and physical layers of a distributed control system  <b>M4</b> Critically examine the application of local area network communication and network types to distributed control systems	<b>D2</b> Critically evaluate the performance of the operator interface in a DCS and its associated hardware

Pass	Merit	Distinction
<b>L03</b> Suggest appropriate techniques to specify and implement a simple Distributed Control System		<b>D3</b> Analyse the interfacing, structure, and performance of a good alarm system
<p><b>P7</b> Review the application and implementation of the DCS systems</p> <p><b>P8</b> Determine appropriate techniques for the application of DCS in different environments</p> <p><b>P9</b> Design and implement a simple DCS to satisfy predefined parameters</p>	<p><b>M5</b> Develop a high level programme for a typical plant problem</p> <p><b>M6</b> Explore the hardware and software configuration of a typical plant problem, making use of various operator display configurations</p>	
<b>L04</b> Develop programmes to use machine interfaces to monitor and control the behaviour of a complex system		<b>D4</b> Analyse and justify the choice of hardware, software and communication systems and its strategy in terms of architecture, system requirements, system integration and toolkits available
<p><b>P10</b> Explain the importance of the control principles and supervision of a DCS</p> <p><b>P11</b> Apply HMI to different process control applications and understand the alarm reporting</p> <p><b>P12</b> Demonstrate the role of the operator interface, associated hardware, diagnostics and maintenance for a DCS</p>	<p><b>M7</b> Show how the configuration control procedures ensure data integrity</p> <p><b>M8</b> Explore the requirements for in-built diagnostics and maintenance diagnostic routines</p>	

## Recommended Resources

### Textbooks

BAILEY, D. and WRIGHT, E. (2003) *Practical SCADA for Industry*. Newnes.

BOYER, S. (2004) *SCADA-Supervisory Control and Data Acquisition System*. 3rd Ed. The Automation Systems and Automation Society (ISA) publication.

SHARMA, K. (2011) *Overview of Industrial Process Automation*. Elsevier.

### Links

This unit links to the following related units:

*Unit 40: Commercial Programming Software*

*Unit 54: Further Control Systems Engineering*

# Unit 42: Further Programmable Logic Controllers (PLCs)

<b>Unit code</b>	<b>H/615/1510</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Programmable Logic Controllers (PLCs) were invented by the American Richard ('Dick') Morley in 1969, to be used in the manufacture of cars. Prior to that date production lines had been controlled by a mass of hard-wired relays. Using programmable devices in their place meant that changes in production could be implemented much faster without the need to rewire control circuits.

The aim of this unit is to further develop students' skills in the use of PLCs and their specific applications within engineering and manufacturing. Among the topics included in this unit are: device interface methods, PLC signal processing and communications with other devices, PLC programming methodology and alternative programmable control devices.

On successful completion of this unit students will be able to research the design, selection and use of PLCs as part of a larger system, programme a PLC to solve an industrial process problem for a given application and illustrate the alternative strategies for using other available types of programmable control devices.

## Learning Outcomes

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

1. Discuss the selection of a specific PLC for a given industrial application.
2. Evaluate how PLCs exchange information and process signals with other devices.
3. Design a PLC programme to solve an industrial process problem for a given application.
4. Analyse alternative strategies using other types of programmable control devices in industrial applications.

## Essential Content

### LO1 **Discuss the selection of a specific PLC for a given industrial application**

*PLC selection:*

Common PLC industrial applications

Different PLC types, their features and PLC manufacturers

External input and output devices: analogue and digital

PLC operational characteristics: speed, current, voltages, memory

Alternative PLC modules available: Relay, Triac, Transistor, Analogue to Digital

### LO2 **Evaluate how PLCs exchange information and process signals with other devices**

*PLC signal processing and communications with other devices:*

Communication links and standards

Networked bus systems

Supervisory Control and Data Acquisition (SCADA) systems and Human Machine Interfaces (HMIs)

**LO3 Design a PLC programme to solve an industrial process problem for a given application**

*PLC programming methodology:*

Fundamentals of logic–ladder diagrams and other programming structures

PLC programming methods used of PLCs in accordance with IEC 61131

Logic functions: AND, OR, NOT, EXOR

Number systems used by PLCs: Binary, Hexadecimal, Octal, BCD

System input and output allocation data

Advanced functions: registers, Analogue to Digital (AtoD), performing calculations, high-speed counters and timers

Program test and debug software functions

Fault-finding of systems using PLC software remotely

Software toolbox elements

Virtual PLC simulations

**LO4 Analyse alternative strategies for using other types of programmable control devices in industrial applications**

*Alternative programmable control devices:*

Programmable Logic Device (PLD)

Peripheral Interface Controller (PIC)

Microcontrollers

Industrial computers

*Programmable device interface methods:*

Relays and solid state relays

Opto couplers

Opto isolators

Motor driver interface integrated circuits

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Discuss the selection of a specific PLC for a given industrial application		<b>D1</b> Evaluate and justify the selection of a specific PLC for an industrial application
<p><b>P1</b> Investigate the key industrial application characteristics of a given industrial application</p> <p><b>P2</b> Compare the operational features and characteristics of PLCs from several manufacturers</p>	<b>M1</b> Justify the choice of a specific PLC suitable for a given industrial application	
<b>LO2</b> Evaluate how PLCs exchange information and process signals with other devices		<b>D2</b> Provide justified and valid rationale for the convergence of PLCs/HMIs and SCADA control systems
<p><b>P3</b> Illustrate the main differences between communication links and standards used within PLC systems</p> <p><b>P4</b> Review the advantages of using networked bus PLC systems</p>	<p><b>M2</b> Show how PLCs in industry integrate with HMIs and SCADA</p> <p><b>M3</b> Evaluate the use of SCADA and HMIs in industry</p>	

Pass	Merit	Distinction
<b>L03</b> Design a PLC programme to solve an industrial process problem for a given application		<b>D3</b> Critically evaluate a PLC programme used to solve an industrial application problem
<b>P5</b> Design a PLC programme to solve an industrial application problem  <b>P6</b> Demonstrate the use of PLC programming and simulation software in a given application	<b>M4</b> Demonstrate the use of test and debug software to correct PLC program faults  <b>M5</b> Explore the practical uses of PLC advanced functions	
<b>L04</b> Analyse alternative strategies for using other types of programmable control devices in industrial applications		<b>D4</b> Critically evaluate the selection of an alternative programmable device in a given application
<b>P7</b> Review the different types of programmable control devices available  <b>P8</b> Examine an industrial application to determine the required characteristics of a control device	<b>M6</b> Review the problems faced by using alternative devices in an industrial environment	



## Recommended Resources

### Textbooks

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

KAMEL, K. and KAMEL, E. (2013) *Programmable Logic Controllers: Industrial Control*. McGraw-Hill Education.

MORTON, J. (2005) *The PIC Microcontroller: Your Personal Introductory Course*. 3rd Ed. Newnes.

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

### Websites

[www.seipub.org/](http://www.seipub.org/) Science and Engineering Publishing Company  
International Journal of Information and Computer  
Science  
(Journal)

<http://www.airccse.org/> AIRCC Publishing Corporation  
International Journal of Computer Science, Engineering  
and Information Technology  
(IJCSEIT) (Journal)

### Links

This unit links to the following related units:

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

*Unit 6: Mechatronics*

*Unit 40: Commercial Programme Software*

# Unit 43: Further Electrical Machines and Drives

**Unit code** K/615/1511

**Unit level** 5

**Credit value** 15

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## Introduction

Electric machines are the most common devices used to perform the actuator function in an industrial control loop. They are an indispensable part of engineering processes and are the workhorse in both commercial and industrial applications.

The aim of this unit is to continue developing the skills in the use and application of electrical machines, particularly direct current (DC) and alternating current (AC) drives.

Among the topics included in this unit are: an introduction to electrical machines and drives, and their characteristics, starting and braking, loading conditions, ratings, and their control.

On successful completion of this unit students will be able to explain the operation of different motors used in industry, describe the different types of industrial drives used in various disciplines, assess the importance of electrical machines and their drives for a given industrial application, analyse their performances and suggest appropriate solutions using a variety of possible methods.

## **Learning Outcomes**

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

1. Explore the principles of operation and the characteristics of electrical machines and their industrial applications.
2. Illustrate the fundamentals of power electronics converters used in power processing units for electric drives.
3. Demonstrate the fundamentals of DC drives and their industrial applications.
4. Demonstrate the fundamentals of AC drives and their industrial applications.

## Essential Content

### LO1 **Explore the principles of operation and the characteristics of electrical machines and their industrial applications**

*Principles of operation and characteristics of electrical machines and their industrial applications:*

Introduction to electrical machines, concepts of electrical machines and their classification

Principles of operation of DC machines and their characteristics

Principles of operation of three-phase induction machines and their characteristics

Principles of operation of synchronous machines and their characteristics

Introduction to special machines

Simulation using Matlab/Simulink or similar commercially available software

### LO2 **Examine the fundamentals of power electronics converters used in power processing units for electric drives**

*Fundamentals of power electronics converters used in power processing units for electric drives:*

Concepts of electrical drives and their classification

DC to DC converters (Choppers), AC to DC converters (Rectifiers), DC to AC converters (Inverters), AC to AC converters (Cyclo-converters)

Simulation using Matlab/Simulink or similar commercially available software

### **LO3 Demonstrate the fundamentals of DC drives and their industrial applications**

*Fundamentals of DC drives and their industrial applications:*

Introduction to DC drives and their application to emerging areas such as smart grid and renewable energy sources

Operating modes of DC drives; single-phase drives, three-phase drives, chopper drives, two/four quadrant operation drives

Application; closed loop control of DC drives

Simulation using Matlab/Simulink or similar commercially available software

### **LO4 Demonstrate the fundamentals of AC drives and their industrial applications**

*Fundamentals of AC drives and their industrial applications:*

Introduction to AC drives and their industrial application such as smart grid and renewable energy sources

Induction motor drives: voltage controls, frequency controls, current controls, voltage, current and frequency control, and closed loop control induction motor

Synchronous motor drives: frequency control and closed loop control of synchronous motor drives

Simulation using Matlab/Simulink or similar commercially available software

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<p><b>LO1</b> Explore the principles of operation and the characteristics of electrical machines and their industrial applications</p>		<p><b>D1</b> Critically evaluate the performance of a given electrical machine using Matlab/Simulink or similar commercially available software to corroborate its performance or otherwise</p>
<p><b>P1</b> Discuss the different types of electrical machines and cite their industrial applications</p> <p><b>P2</b> Illustrate the principle of operation of electrical machines with the aid of circuit diagrams and waveforms</p> <p><b>P3</b> Investigate the construction, operation and characteristics of a given electrical machine</p>	<p><b>M1</b> Utilise Matlab and Simulink or similar commercially available software for modelling and simulation of a given electrical machine</p> <p><b>M2</b> Analyse the characteristics of a given electrical machine from its equivalent circuits</p>	

Pass	Merit	Distinction
<p><b>L02</b> Examine the fundamentals of power electronics converters used in power processing units for electric drives</p>		<p><b>D2</b> Critically evaluate the performance of a given converter using Matlab/Simulink software to corroborate its performance or otherwise</p>
<p><b>P4</b> Illustrate, with the aid of circuit diagrams and waveforms, the operation of a given uncontrolled or controlled converter (half wave/full wave/three-phase)</p>	<p><b>M3</b> Show how Matlab and Simulink or similar commercially available software may be used for modelling and simulation of a given converter</p>	
<p><b>P5</b> Illustrate, with the aid of circuit diagrams and waveforms, the impact of resistive and inductive loads on the converter's input and output characteristics</p>	<p><b>M4</b> Evaluate the key performance characteristics of a given converter</p>	
<p><b>P6</b> Investigate the importance of input and output filters in a given converter</p>		

Pass	Merit	Distinction
<p><b>L03</b> Demonstrate the fundamentals of DC drives and their industrial applications</p>		<p><b>D3</b> Analyse the impact of DC drives on the operation and performance of an industrial control system</p>
<p><b>P7</b> Discuss the operating modes of DC drives and control parameters</p> <p><b>P8</b> Explain the importance of DC drives in industrial applications</p> <p><b>P9</b> Discuss the principle operations of single/three-phase choppers with the aid of circuit diagrams and waveforms</p> <p><b>P10</b> Illustrate, with the aid of circuit diagrams and waveforms, the implementation of closed loop control of DC drives</p>	<p><b>M5</b> Develop an open loop block diagram of a DC motor and derive the relationship between the input and the output of the systems</p> <p><b>M6</b> Evaluate how DC drive circuits are used to control the speed of DC motors</p>	



Pass	Merit	Distinction
<p><b>LO4</b> Demonstrate the fundamentals of AC drives and their industrial applications</p>		<p><b>D4</b> Analyse the impact of AC drives on the operation and performance of an industrial control system</p>
<p><b>P11</b> Illustrate the operating modes of AC drives, their control parameters and their importance in industrial applications</p>	<p><b>M7</b> Develop an open loop block diagram of an induction motor and derive the relationship between the input and the output of the systems</p>	
<p><b>P12</b> Illustrate, with the aid of circuit diagrams and waveforms, the principles of operations of single/three-phase AC drives</p>	<p><b>M8</b> Evaluate how AC drive circuits are used to control the speed of induction and synchronous motors</p>	
<p><b>P13</b> Review, with the aid of circuit diagrams and waveforms, the implementation of closed loop control of AC drives</p>		

## Recommended Resources

### Textbooks

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

RASHID, M.H. (2004) *Circuits, Devices and Applications*. 3rd Ed. Prentice Hall.

RASHID, M.H. (2001) *Power Electronics Handbooks*. 1st Ed. Academic Press.

### Links

This unit links to the following related units:

*Unit 21: Electrical Machines*

# Unit 44: Industrial Power, Electronics and Storage

**Unit code** M/615/1512

**Unit level** 5

**Credit value** 15

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## Introduction

This unit presents a wide-ranging introduction to the field of existing and renewable energy systems. There are many alternative sources of energy (some 'green') which can be converted to an electrical form, providing energy for transport, heat/cooling and lighting, as well as energy for various industrial processes and applications.

Power electronic converters are an essential component of renewable and distributed energy sources, including wind turbines, photovoltaics, marine energy systems and energy storage systems. It is necessary to gain a clear understanding of, and be able to examine, the technical implications of providing sustainable electrical energy to meet the energy demand of the future.

The unit will also explore the potential impacts of climate change and why more, and different forms of, sustainable energy sources are required together with the need for energy efficiency measures.

By the end of this unit students will be able to examine the technological concepts behind providing a sustainable electrical energy supply for the future. They will also be able to describe how the fundamental technical and economic processes and drivers at play in the electrical power industry affect the selection and use of energy sources.

## **Learning Outcomes**

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

1. Evaluate energy demand to determine the technology and methods of energy production.
2. Discuss current energy efficiency measures, technologies and policies specific to the building and transportation sectors.
3. Analyse the control techniques of power electronics for renewable energy systems.
4. Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid.

## Essential Content

### LO1 Evaluate the energy demand to determine the technology and methods of energy production

#### *Energy demand:*

Historical energy production, energy consumption, environmental aspects and global warming

The need for energy systems and global energy demand over the short to long term

Environmental effects associated with energy generation and consumption

Practicality, benefits, drawbacks and effectiveness of renewable energy sources

Overview of renewable energy technologies (wind, solar, bio, hydro, geothermal) and the associated costs

Future energy trends, scenarios and sustainable energy sources

### LO2 Explore current energy efficiency measures, technologies and policies specific to the building and transportation sectors

#### *Energy auditing, management, costs, requirements, bench marking and optimisation:*

Energy management, planning, monitoring, policy, ecology and environment

#### *Energy and buildings:*

Overview of the significance of energy use and energy processes

Internal and external factors on energy use and the attributes of the factors

Status of energy use in buildings and estimation of energy use in a building

Standards for thermal performance of building envelope and evaluation of the overall thermal transfer

Measures and technologies to improve energy efficiency in buildings

*Energy and electric vehicles:*

Electrical vehicle configurations, requirements, and circuit topology; electric and plug in hybrid vehicles

Policies, measures and technologies to support more sustainable transportation

Use of Matlab/Simulink or alternative appropriate software to model, simulate and analyse the energy efficiency of a typical standard house or electric vehicle

**LO3 Analyse the control techniques of power electronics for renewable energy systems**

*Control techniques:*

Environmental aspects of electrical energy conversion using power electronics

Introduce design criteria of power converters for renewable energy applications

Analyse and comprehend the various operating modes of wind electrical generators and solar energy systems

Introduce the industrial application of power converters, namely AC to DC, DC to DC and AC to AC converters for renewable energy systems

Explain the recent advancements in power systems using the power electronic systems. Introduction to basic analysis and operation techniques on power electronic systems

Functional analysis of power converters' main topologies

Use of Matlab/Simulink to model, simulate and analyse the dynamic behaviour of a simple renewable energy system

**LO4 Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid**

*Impact of renewable resources:*

Safe and secure operation of a simple power system

Standalone and grid connected renewable energy systems

Introduction to smart grid, features, functions, architectures, and distributed generation. Grid interactive systems, grid tied systems, inverters, and application of its devices

Smart homes, power management, smart grid, intelligent metering

Communication technologies and power electronics modules for smart grid network, importance of power electronics in smart grid, for example energy storage (electrical, chemical, biological, and heat), and the future of smart grid

Use of Matlab/Simulink to model, simulate and analyse the dynamic behaviour of a standard smart grid.

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Evaluate the energy demand to determine the technology and methods of energy production		<b>D1</b> Critically evaluate the performance of a renewable energy system and the technologies used in energy efficiency improvement
<b>P1</b> Investigate current energy sources, demand and their impact on the environment  <b>P2</b> Examine the benefits and effectiveness of renewable energy sources  <b>P3</b> Explore renewable energy technologies and their costs	<b>M1</b> Determine the use of energy sources to assess their global impact on energy demand  <b>M2</b> Evaluate the effectiveness and drawbacks of renewable energy systems for short and long term energy demands	
<b>L02</b> Explore current energy efficiency measures, technologies and policies specific to the building and transportation sectors		
<b>P4</b> Discuss current energy efficiency measures  <b>P5</b> Determine the main factors that impact on energy use and efficiency in a building  <b>P6</b> Discuss the technologies that could be used to support more sustainable transport	<b>M3</b> Apply modelling of energy management in a building or electric vehicle using Matlab/Simulink (or equivalent)  <b>M4</b> Evaluate the selection of suitable technologies to improve energy efficiency in a building or electric vehicle	<b>D2</b> Analyse the dynamic performance of a power electronic converter for a given renewable energy source and calculate the energy and cost savings against conventional power sources, including consideration for development and installation costs



Pass	Merit	Distinction
<p><b>L03</b> Analyse the control techniques of power electronics for renewable energy systems</p>		<p><b>D3</b> Critically evaluate the dynamic performance of integrating renewable energy sources to the smart grid network using a standard industrial based software, such as Matlab/Simulink software (or equivalent)</p>
<p><b>P7</b> Analyse the applications of power electronics in renewable energy applications</p> <p><b>P8</b> Determine the industrial application of power electronic converters</p> <p><b>P9</b> Analyse the power electronic converter topologies and their principles of operation</p>	<p><b>M5</b> Simulate a simple power converter for a typical renewable energy system using a standard software package such as Matlab/Simulink (or equivalent)</p> <p><b>M6</b> Critically analyse the use of the power converter selected above for a renewable energy application</p>	
<p><b>L04</b> Investigate the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid</p>		<p><b>D4</b> Critically analyse the impact of renewable energy sources and their integration to the grid using a standard industrial based software such as Matlab/Simulink (or equivalent)</p>
<p><b>P10</b> Investigate the safe operation of a smart power system</p> <p><b>P11</b> Investigate the principle of operation of standalone and grid connected renewable energy systems</p> <p><b>P12</b> Discuss the features of a smart grid network</p> <p><b>P13</b> Determine the importance of power electronics in smart grid and energy storage</p>	<p><b>M7</b> Analyse how power electronic converters are used in smart grid networks</p> <p><b>M8</b> Evaluate the issues associated with integrating renewable energy sources to the grid</p>	

## Recommended Resources

### Textbooks

ABU-RUB, H., MALINOWSKI, M. and AL-HADDAD, K. (2014) *Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications*.

John Wiley & Sons.

EKANAYAKE, J. and JENKINS, N. (2012) *Smart Grid Technology and Applications*.

John Wiley & Sons.

RASHID, M.H. (2013) *Power Electronics: Circuits, Devices and Applications*.

4th Ed. Pearson.

TWIDELL, J. and WEIR, T. (2006) *Renewable Energy Resources*. 2nd Ed.

Taylor & Francis.

### Links

This unit links to the following related units:

*Unit 51: Sustainability*

*Unit 53: Utilisation of Electrical Power*

## Unit 45:

# Industrial Systems

<b>Unit code</b>	<b>T/615/1513</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

The speed and efficiency of many industrial processes is due, largely, to the control systems selected for the application and the engineer's ability to apply the most appropriate technology for their operation.

This unit presents a structured approach to the development of advanced electronic solutions in a range of industrial situations. An essential requirement here is the engineer's ability to utilise the most appropriate technology for each application, to ensure the most efficient monitoring and control of variables such as pressure, temperature and speed.

Among the topics included in this unit are techniques and applications of electrical and electronic engineering, as they apply to various branches of industry, such as component handling, controlling the speed or torque of a motor or responding to change of circumstances in a process.

On successful completion of this unit students will be able to describe system elements and consider their overall characteristics. This provides opportunity for analytically assessing the accuracy and repeatability of electronic instruments.

### Learning Outcomes

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

1. Describe the main elements of an electronically controlled industrial system.
2. Identify and specify the interface requirements between electronic, electrical and mechanical transducers and controllers.
3. Apply practical and computer-based methods to design and test a measurement system.
4. Apply appropriate analytical techniques to predict the performance of a given system.

## Essential Content

### LO1 Describe the main elements of an electronically controlled industrial system

*Fundamental concepts of industrial systems:*

Discrete control

Input and output devices; open and closed loop systems

Describe the system elements and the principles and applications of important and representative AC and DC motors

### LO2 Identify and specify the interface requirements between electronic, electrical and mechanical transducers and controllers

*Interfacing and transducers:*

Discrete automation using relays and solenoids, AC and DC motors, pneumatic, hydraulic and electrical actuators, and other transducers and devices for measuring and comparing physical parameters

Interfacing between electrical, electronic and mechanical transducers

Practical measurement using sensors and transducers, process actuators for temperature and pressure control

### LO3 Apply practical and computer-based methods to design and test a measurement system

*System modelling and analysis:*

The use of transfer functions to help predict the behaviour and constancy of an industrial process, including accuracy, resolution and tolerances, repeatability and stability, sensitivity and response time

Dealing with error and uncertainty in industrial systems

Use of computer packages in measurement and control, and dealing with uncertainty and errors in systems

### LO4 Apply appropriate analytical techniques to predict the performance of a given system

Consideration of current trends in technology, including the future of industrial systems, the impact of digital developments, the increase of wireless and remote control and the Internet of Things

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Describe the main elements of an electronically controlled industrial system		<b>D1</b> Critically examine the performance of an electronically controlled system to make recommendations for improvement
<p><b>P1</b> Describe the main elements of an electronically controlled industrial system</p> <p><b>P2</b> Review the main concepts underlying electronically controlled industrial systems</p>	<p><b>M1</b> Analyse the characteristics of an electronically controlled industrial system by applying a variety of techniques to the solution of a given problem</p>	
<b>L02</b> Identify and specify the interface requirements between electronic, electrical and mechanical transducers and controllers		<b>D2</b> Critically investigate the behaviour of a given control system to compare different electrical, electronic, and mechanical approaches to control
<p><b>P3</b> Identify the interface requirements between electronic, electrical and mechanical transducers and controllers</p> <p><b>P4</b> Justify the choice of transducers and controllers for a given task</p>	<p><b>M2</b> Predict the behaviour of an electronically controlled industrial system by applying a variety of transducers to the solution of a given problem and choose a 'best' solution</p>	
<b>L03</b> Apply practical and computer-based methods to design and test a measurement system		<b>D3</b> Critically evaluate the performance of an ideal measurement system compared to a real circuit
<p><b>P5</b> Apply practical and computer-based methods to design and test a measurement system</p> <p><b>P6</b> Explain the use of practical and analytical methods in creating and testing a measurement system</p>	<p><b>M3</b> Interpret the characteristics and behaviour of an existing electronic measurement system by applying a variety of methods to find a solution to a given problem</p>	

Pass	Merit	Distinction
<b>LO4</b> Apply appropriate analytical techniques to predict the performance of a given system		<b>D4</b> Analyse an existing industrial system by using appropriate analytical techniques Provide justified recommendations to improve the performance
<b>P7</b> Apply the main analytical techniques to explain the performance of a given system	<b>M4</b> Evaluate the characteristics of an electronically controlled industrial system by applying a variety of analytical techniques to the solution of a given problem	

## Recommended Resources

### Textbooks

- BIRD, J. (2013) *Electrical Circuit Theory and Technology*. Routledge.
- HUGHES, E. et al. (2012) *Electrical and Electronic Technology*. Pearson.
- REHG, J.A. and SARTORI, G.J. (2005) *Industrial Electronics*. Prentice-Hall.
- WILAMOWSKI, B.M. and IRWIN, J.D. (2011) *The Industrial Electronic Handbook: Fundamentals of Industrial Electronics*. CRC Press.

### Websites

- |   |   |
|---|---|
| <a href="http://www.bath.ac.uk/">http://www.bath.ac.uk/</a>                     | University of Bath<br>Patents<br>(General Reference)                                  |
| <a href="http://www.bsigroup.com/">http://www.bsigroup.com/</a>                 | Business Standards Institution<br>Standards Catalogue<br>(General Reference)          |
| <a href="https://www.ieee.org/">https://www.ieee.org/</a>                       | Institute of Electrical and Electronics Engineers<br>Standards<br>(General Reference) |
| <a href="http://www.theiet.org/">http://www.theiet.org/</a>                     | Institution of Engineering and Technology<br>(General Reference)                      |
| <a href="http://www.newelectronics.co.uk/">http://www.newelectronics.co.uk/</a> | New Electronics<br>Digital Magazine<br>(Journals)                                     |
| <a href="http://www.theiet.org/">http://www.theiet.org/</a>                     | Institution of Engineering and Technology<br>(Journals)                               |
| <a href="http://www.epemag.com/">http://www.epemag.com/</a>                     | Everyday Practical Electronics<br>(Journals)  |
| <a href="https://www.ieee.org/">https://www.ieee.org/</a>                       | Institute of Electrical and Electronics Engineers<br>(Journals)                       |

### Links

This unit links to the following related units:

*Unit 19: Electrical and Electronic Principles*

*Unit 16: Instrumentation and Control Systems*

# Unit 46: Embedded Systems

<b>Unit code</b>	<b>A/615/1514</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

An embedded system is a device or product which contains one or more tiny computers hidden inside it. This 'hidden computer', usually a microcontroller, is used to control the device and give it added 'intelligence'. Embedded systems are a key aspect of modern engineering and are applied in areas as diverse as automotive, medical, and industrial, and in the home and office. In many cases, embedded systems are linked together in networks. Embedded systems are the basis of a new wave of engineering design and practice, notably in machine-to-machine communication and in the Internet of Things.

This unit builds on introductory knowledge students have already gained in electronic circuits. It develops their knowledge of computer hardware, focussing on the small, low-cost type of computer (i.e. a *microcontroller*), usually used in embedded systems. It then develops skill in devising circuits which operate external to the microcontroller and interface with it; generally, these relate to sensors, actuators, human interface or data transfer. In parallel with this, students will be developing programming skills, writing programmes which download straight to the microcontroller and cause it to interact with its external circuit. Students will also explore the wider context of embedded systems, learning how they are applied in 'hi-tech' applications, in many cases revolutionising our ability to undertake certain activities.

Unit assessment will require the design, development, construction and commissioning of an embedded system, meeting a given design brief; this will develop skills which are in much demand in industry. A written assignment, exploring one or more of the many fast-moving embedded system applications in use today, will also be completed.



## **Learning Outcomes**

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

1. Explore the principle features of a microcontroller and explain the purpose of its constituent parts.
2. Design and implement simple external circuitry, interfacing with a given microcontroller.
3. Write well-structured code in an appropriate programming language, to simulate, test and debug it.
4. Evaluate the applications of embedded systems in the wider environment, including in networked systems.

## Essential Content

### LO1 Explore the principle features of a microcontroller and explain the purpose of its constituent parts

#### *Microcontroller architecture:*

CPU (Central Processing Unit), the instruction set, programme memory, data memory, input/output (I/O), data and address buses, van Neumann and Harvard structures

Peripherals, to include digital I/O, counter/timers, analogue to digital converter (ADC), pulse width modulation (PWM), Serial Peripheral Interface (SPI), Universal Asynchronous Receiver/Transmitter (UART)

Memory types (overview only): Flash, Static RAM (Random Access Memory), EEPROM (Electrically Erasable Read Only Memory) and their applications

Simple interrupt concepts

### LO2 Design and implement simple external circuitry, interfacing with a given microcontroller

#### *Simple digital interfacing:*

Switches, light emitting diodes (LEDs), keypads, and 7-segment displays

#### *DC and ADC applications:*

DC load switching (e.g. of small motor or solenoid), use of PWM to provide variable DC motor speed control

ADC application, including range and resolution

Signal conditioning for analogue inputs, including simple op amp circuits to provide gain or level shifting

Interfacing to external devices with serial capability, applying SPI and UART

Power supply and clock oscillator

**LO3 Write well-structured code in an appropriate programming language, to simulate, test and debug it**

*The development cycle:*

Integrated Development Environment, Assembler and High Level Languages, compilers, simulators, completing an in-circuit debug

Devising a code structure e.g. using flow diagrams and pseudo code

*Programming languages and codes:*

Review of an appropriate high level programming language (which is likely to be C). Language structure, data types, programme flow, looping, branching, and conditional

Developing application code: initialisation, data input, conditional branching and looping, data output

Code simulation, download, test and debug

**LO4 Evaluate the applications of embedded systems in the wider environment, including in networked systems**

*Review of application of embedded systems:*

Using example sectors e.g. motor vehicle, smart buildings, medical, office, wearable. Review possible limiting factors in an embedded design e.g. power supply, reliability, security

Review of current trends in embedded systems, including the Internet of Things and machine-to-machine

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Explore the principle features of a microcontroller and explain the purpose of its constituent parts		<b>D1</b> Critically evaluate microcontroller architectures and subsystems, exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)
<b>P1</b> Examine the hardware interfaces and the software architecture of a selected microcontroller <b>P2</b> Explain the function of the main microcontroller elements	<b>M1</b> Evaluate microcontroller architectures and subsystems, exploring characteristics such as electrical, timing and size (e.g. of memory or ALU)	
<b>L02</b> Design and implement simple external circuitry, interfacing with a given microcontroller		<b>D2</b> Critically evaluate the functionality of external circuitry under a range of operating conditions
<b>P3</b> Design simple external circuits, sensors and actuators, from available designs <b>P4</b> Apply simple external circuits, demonstrating effective interfacing and adequate functionality	<b>M2</b> Adapt and improve simple external circuits, sensors and actuators, from available designs <b>M3</b> Assess simple external circuits and evaluate functionality	
<b>L03</b> Write well-structured code in an appropriate programming language, to simulate, test and debug it		<b>L03</b> <b>D3</b> Critically evaluate the code developed through simulation and in the hardware, demonstrating excellent functionality <b>D4</b> Critically evaluate emerging applications of embedded systems, clearly identifying trends and recognising technical and economic factors
<b>P5</b> Write well-structured working code, to meet an identified need <b>P6</b> Test and de-bug code through simulation in the hardware, demonstrating functionality	<b>M4</b> Adapt and improve given examples to produce well-structured and reliable code with meaningful programme identifiers, to meet an identified need	
<b>L04</b> Evaluate the applications of embedded systems in the wider environment, including in networked systems		
<b>P7</b> Explain the uses of embedded systems in current and emerging applications	<b>M5</b> Evaluate current and emerging applications of embedded systems, e.g. in motor vehicles, health or the Internet of Things	

## Recommended Resources

### Textbooks

BLUM, J. (2013) *Exploring Arduino*. Wiley.

TOULSON, R. and WILMSHURST, T. (2012) *Fast and Effective Embedded System Design: Applying the ARM*. Newnes.

WILMSHURST, T. (2009) *Designing Embedded Systems with PIC Microcontrollers: Principles and Applications*. 2nd Ed. Newnes.

### Links

This unit links to the following related units:

*Unit 52: Further Electrical, Electronic and Digital Principles*

*Unit 54: Further Control Systems Engineering*

# Unit 47: Analogue Electronic Systems

<b>Unit code</b>	<b>F/615/1515</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Analogue electronic systems are still widely used for a variety of very important applications and this unit explores some of the specialist applications of this technology.

The aim of this unit is to further develop students' understanding of the application of analogue and digital devices in the design of electronic circuits. Students will investigate the design and testing of electronic systems based on a sound theoretical knowledge of the characteristics of electronic devices supported by Electronic Computer Aided Design (ECAD) tools, and then construct and test sample physical circuits. Students will be able to explain the characteristics of analogue and digital subsystems and the representation and processing of information within them.

Upon completion of this unit students will be aware of techniques employed in the design and evaluation of analogue and digital subsystems used in the development of complete electronic systems.

## Learning Outcomes

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

1. Design single stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances.
2. Develop functional subsystems through an understanding of the characteristics of operational amplifiers.
3. Examine the characteristics of information represented in analogue and digital format to assess techniques for the conversion of signals between analogue and digital formats.
4. Design electronic circuits using physical components.

## Essential Content

### LO1 Design single stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances

#### *Bipolar Junction Transistor models:*

The theory of operation of the Bipolar Junction Transistor (BJT), together with DC biasing conditions of BJT for linear amplifier applications

Characteristics of common emitter, common collector and common base amplifier configurations

DC  $h_{FE}$  and small signal common emitter h-parameter model and the common emitter hybrid- $\pi$  model of the BJT

Show  $g_m \approx I_C/26\text{mV}$  for silicon BJT at room temperature

#### *Bipolar Junction Transistor small signal amplifiers:*

Four-resistor BJT common-emitter amplifier and its predicted AC voltage gain

ECAD used to determine the mid-band voltage gain and input and output resistances

The effect of input, output and emitter decoupling capacitors and tuned L-C collector load

#### *Bipolar Junction Transistor large signal amplifiers:*

Examples of class A, B, AB, C and D large signal amplifiers

Use of ECAD to investigate the characteristics of sample power amplifier circuits

#### *Field Effect Transistor models:*

The theory of operation of the Field Effect Transistor (FET) and the Metal Oxide Semiconductor FET (MOSFET)

Application of FETs and MOSFETs in switching circuits and linear amplifiers, including complementary MOSFET stages

Apply FET AC equivalent circuit models

Examples of specific applications of FET that have been developed for specialist applications

## LO2 **Develop functional subsystems through an understanding of the characteristics of operational amplifiers**

### *Operational amplifier components:*

Circuit configuration and the operation of the long-tailed pair differential amplifier, current mirror and class AB amplifiers and relate these to circuits of operational amplifiers published in manufacturers' data sheets

### *Operational amplifier characteristics:*

Characteristics of practical operational amplifiers, including open loop gain, input offset voltage, common mode input range, saturated output levels, slew rate and gain-bandwidth product

Describe the ideal operational amplifier model and relate these to the specifications of practical operational amplifiers

Characteristics of the operational amplifier with negative feedback applied

### *Operational amplifier applications:*

Description of a range of subsystems, including the voltage comparator, inverting and non-inverting amplifier, summing amplifier, differential amplifier, linear voltage regulator, switched mode voltage regulator, differentiator, integrator, filters, sinusoidal oscillator, Schmitt trigger and Schmitt oscillator

Sub-system specifications and evaluations in time and frequency domains, as appropriate

Use of ECAD tools



**LO3 Examine the characteristics of information represented in analogue and digital format to assess techniques for the conversion of signals between analogue and digital formats**

*The characteristics of information represented electronically:*

Comparison of the implications of capturing, processing and storing information represented by analogue signals and by digital data, including amplitude range, frequency range, accuracy, resolution, linearity, drift, noise and signal-to-noise ratio

*Digital to analogue and analogue to digital converters:*

Evaluation and comparison of digital to analogue converters based on the binary weighted resistor and the R/2R ladder network techniques

Evaluate and comparison of analogue to digital converters based on the single ramp, successive approximation and parallel comparator (flash) techniques

Advantages of using non-linear conversion curves in communications applications. Techniques for multichannel operation using multiplexing and demultiplexing techniques applied to both digital and analogue channels

Examples of commercially available converters and the implementation of analogue input and output ports to digital processing devices found within embedded systems

**LO4 Design electronic circuits using physical components**

*Sub-system design, implementation and evaluation:*

Examples of electronic subsystems

Development of specifications to achieve a useful function and design of circuits to achieve this function

Simulation of design using ECAD tools

Building of circuits as designed, application of a range of appropriate bench tests to evaluate its operation, and comparing its actual operation to the design specifications and the simulation results

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Design single stage analogue amplifier circuits to predict and measure, by simulation, the gain, frequency response and input and output resistances		<b>D1</b> Critically analyse the relationship between the circuit design and simulation results, making justified and operable recommendations for changes to the specifications of the circuits
<b>P1</b> Design single stage amplifier circuits and measure key aspects by simulation	<b>M1</b> Relate simulation results to circuit designs and analyse discrepancies	
<b>L02</b> Develop functional subsystems through an understanding of the characteristics of operational amplifiers		<b>D2</b> Communicate circuit designs to specialist audiences  The implications of manufacturers' data sheets are understood so that practical designs can be produced
<b>P2</b> Present the key components of operational amplifiers  <b>P3</b> Determine the operation of subsystems from the ideal model of the operational amplifier and by simulation results	<b>M2</b> Design operational amplifier subsystems simulated in time and frequency domains  <b>M3</b> Critically analyse simulation results with reference to the expected results	

Pass	Merit	Distinction
<p><b>L03</b> Examine the characteristics of information represented in analogue and digital format to assess techniques for the conversion of signals between analogue and digital formats</p>		<p><b>D3</b> Critically evaluate the implications of resolution, conversion time and non-linear conversion curves on accuracy and noise</p>
<p><b>P4</b> Examine the limitations of representing information in both analogue and digital form</p> <p><b>P5</b> Specify the technical characteristics of converters to meet a given set of requirements</p>	<p><b>M4</b> Critically evaluate the characteristics and the limitations of converter topologies and their specific applications</p>	
<p><b>L04</b> Design electronic circuits using physical components</p>		<p><b>D4</b> Communicate circuit designs to specialist audiences, showing variation of circuit function in simulations as a result of design changes or component tolerances</p>
<p><b>P6</b> Design an electronic circuit</p> <p><b>P7</b> Simulated construct and test the design on the bench</p>	<p><b>M5</b> Critically analyse design equations, simulation and bench test results, ensuring discrepancies are recorded and explained</p>	

## Recommended Resources

### Textbooks

LATHI, B.P. and ZHI, D. (2009) *Modern Digital and Analog Communications Systems*. Oxford Series in Electrical and Computer Engineering. 4th Ed. Oxford University Press.

STOREY, N. (2013) *Electronics: A Systems Approach*. 5th Ed. Pearson.

### Links

This unit links to the following related units:

*Unit 19: Electrical and Electronic Principles*

# Unit 48: Manufacturing Systems Engineering

**Unit code** J/615/1516

**Unit level** 5

**Credit value** 15

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## Introduction

Manufacturing systems engineering is concerned with the design and on-going operation and enhancement of the integrated elements within a manufacturing system, which is a very complex activity, even for simple products. The art of manufacturing systems engineering is essentially designing systems that can cope with that complexity effectively.

The aim of this unit is to develop students' understanding of that complexity within a modern manufacturing environment. Among the topics covered in this unit are: elements that make up a manufacturing system, including production engineering, plant and maintenance engineering, product design, logistics, production planning and control, forecast quality assurance, accounting and purchasing, all of which work together within the manufacturing system to create products that meet customers' requirements.

On successful completion of this unit students will be able to explain the principles of a manufacturing system and consider how to design improvements. They will be introduced to all the elements that make up a modern manufacturing system, and they will learn how to optimise the operation of existing systems through discerning use of monitoring data. Some of the elements will be developed in greater depth; of particular importance will be looking at the systems of production planning and control, which are the day-to-day tools used to manage the manufacturing system effectively.

## Learning Outcomes

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

1. Illustrate the principles of manufacturing systems engineering and explain their relevance to the design and enhancement of manufacturing systems.
2. Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system, and then develop an appropriate future state for that system.
3. Outline the impact of different production planning approaches on the effectiveness of a manufacturing system.
4. Define the responsibilities of manufacturing systems engineering and review how they enable successful organisations to remain competitive.

## Essential Content

### LO1 **Illustrate the principles of manufacturing systems engineering and their relevance to the design and enhancement of manufacturing systems**

#### *Manufacturing systems elements:*

Elements to be considered include quality, cost, delivery performance and optimising output

Problem-solving and managing complexity, maintenance scheduling and planning, resource planning and productivity

Effect of testing and data analysis on performance

### LO2 **Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system, and then develop an appropriate future state for that system**

#### *Analysis tools:*

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

Bottle-neck analysis, by using process improvement tools and techniques e.g. value stream analysis, simulation, kanban

Using key performance indicators to understand the performance of a manufacturing system e.g. overall equipment effectiveness, lead-time, cycle time, waiting time, yield, delivery performance, safety metrics

Reviewing key performance indicators; methods for presenting metrics and performance e.g. balanced scorecards, performance dashboards, Andon boards, Gemba walks

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

*Production planning approaches:*

Examples of production planning strategy: push vs pull factors, kanban systems, make to stock, make to order and engineer to order

Production planning approaches such as batch and queue, pull/kanban, just-in-time, modular design, configuration at the final point, and master scheduling

*Production planning management tools:*

Enterprise Resource Mapping (ERP) systems, Material Resource Planning (MRP 2) and Manufacturing Execution systems, ability to managing complexity and resourcing through information technology

Industrial engineering issues: the importance of standard times and the impact on productivity and the costing of products. Standard work underpins the repeatability of process and quality control

**LO4 Review the functions of manufacturing systems engineering and how they enable successful organisations to remain competitive**

*Effectiveness of manufacturing systems:*

Plant layout design, planning and control, productivity and continuous improvement, quality control and equipment effectiveness

Return on investment and capital expenditure, control of the cost of planned maintenance

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



## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Illustrate the principles of manufacturing systems engineering and their relevance to the design and enhancement of manufacturing systems		<b>D1</b> Apply value stream mapping to a production process to evaluate the efficiency of that process by using the current state map to suggest improvements
<b>P1</b> Illustrate the principles of manufacturing engineering <b>P2</b> Explain the relevance of manufacturing systems engineering to the design of a manufacturing system	<b>M1</b> Evaluate the impact that manufacturing systems have on the success of a manufacturing organisation	
<b>LO2</b> Use a range of analysis tools, including value stream mapping, to determine the effectiveness and efficiency of a manufacturing system, and then develop an appropriate future state for that system		<b>D2</b> Review value stream mapping against other production planning methodologies and justify its use as a production planning tool
<b>P3</b> Apply value stream mapping to visualise a production process	<b>M2</b> Identify optimisation opportunities through value stream mapping of a production process	

Pass	Merit	Distinction
<p><b>LO3</b> Outline the impact of different production planning approaches on the effectiveness of a manufacturing system</p>		<p><b>D3</b> Justify the most appropriate production planning technique and its suitability for a particular manufacturing approach, such as make to stock, make to order, or engineer to order</p>
<p><b>P4</b> Identify the common production planning approaches and state their impact on manufacturing systems</p> <p><b>P5</b> Define the types of manufacturing approach, such as make to stock, make to order and engineer to order</p>	<p><b>M3</b> Evaluate the effectiveness of production planning methods</p> <p><b>M4</b> Explore the effectiveness of common production planning techniques to identify which production approach they complement</p>	
<p><b>LO4</b> Review the functions of manufacturing systems engineering and how they enable successful organisations to remain competitive</p>		<p><b>D4</b> Critically consider the elements of an existing manufacturing system to appraise why this is successful</p>
<p><b>P6</b> Define the core responsibilities of a manufacturing systems engineer</p> <p><b>P7</b> Identify the key contributing success factors of a manufacturing system</p>	<p><b>M5</b> Evaluate the impact that a manufacturing systems engineering has on successful manufacturing organisations</p>	

## Recommended Resources

### Textbooks

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

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

SLACK, N. (2013) *Operations Management*. 7th Ed. Pearson.

WOMACK, J., JONES, D. and ROOS, D. (1990) *The Machine That Changed the World*. Free Press.

### Websites

<http://www.industryweek.com/>      Industry Week  
Five Benefits of an MES  
(Article)

### Links

This unit links to the following related units:

*Unit 49: Lean Manufacturing*

*Unit 50: Advanced Manufacturing Technology*

*Unit 51: Sustainability*

## Unit 49:

## Lean Manufacturing

<b>Unit code</b>	<b>L/615/1517</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

Lean manufacturing is a systematic approach to minimising waste in a manufacturing system, by focusing on the activities that add the most value through the eyes of the customer. The basis of lean manufacturing originated in the car industry and was developed by Toyota in Japan. Lean is now used extensively worldwide, in all types and size of organisation, to improve international competitiveness. It is therefore crucial for manufacturing engineers to be able to design and operate manufacturing systems that employ lean successfully

The aim of this unit is to introduce students to the principles and processes of lean manufacturing, so that they can become an effective and committed practitioner of lean in whatever industry sector they are employed in. To do this, the unit will explore the tools and techniques that are applied by organisations practicing lean. The students will consider both the benefits and challenges of using lean manufacturing, and become sufficiently knowledgeable about the most important process tools and techniques to be able to operate and use them.

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

On successful completion of this unit students will be able to explain the common principles of lean manufacturing, compare the Toyota Production System with the now more widely adopted generic approaches to lean manufacturing, utilise a range of the process improvement tools used within lean manufacturing, and demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation.

## **Learning Outcomes**

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

1. Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success.
2. Evaluate the Toyota Production System against the now more widely adopted generic approaches to lean manufacturing.
3. Specify a range of the process improvement tools used within lean manufacturing.
4. Demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation.

## Essential Content

### LO1 **Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success**

#### *Scoping and defining lean manufacturing:*

The common principles of lean manufacturing philosophy

Origins of lean

Defining lean and its importance to the customer

Identifying and eliminating material and process waste that adds no value from the customer's perspective

#### *Benefits and challenges of adopting lean:*

Why an organisation would consider adopting a lean philosophy

Productivity, quality, customer satisfaction, delivery performance

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

Outline the benefits of lean in terms of cost, quality, delivery, customer satisfaction, management complexity and cost to serve

Challenges of implementation: change management, managing expectation, empowerment, motivation, 'burning platform', investment, supply chain

### LO2 **Evaluate the Toyota Production System against the now more widely adopted generic approaches to lean manufacturing**

#### *Toyota Production System:*

Research the Toyota Production System (TPS) and identify the fundamental elements of the TPS and the motivation behind creating the TPS

Compare TPS with the recognised theory and production systems publicised by other global manufacturers: how do they differ and how they are similar?

How the common principles are now being adopted outside manufacturing

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

*Common tools and techniques associated with lean manufacturing and process improvement:*

Seven Wastes, continuous flow, kanban (pull System), just-in-time (JIT), lean simulation activities, value stream mapping, Poke Yoke, 5 Whys (Root Cause Analysis), Total Preventive Maintenance

Plan-do-check-act (PDCA), Single Minute Exchange of Die (SMED), A3 Reporting, Visual Management

*Selecting the most appropriate improvement tool to tackle a problem:*

Tools for improving quality and delivery

**LO4 Demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation**

*Communication:*

Facilitate a small group in the application and use of one of the lean tools (e.g. 5 Whys technique, A3 Report)

Identify factors that influence engagement within a group, facilitation skills and change management

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Examine the common principles of lean manufacturing and how the implementation of a lean production system contributes to business success		<b>D1</b> Critically evaluate the advantages and disadvantages of implementing a lean production system
<b>P1</b> Examine how lean manufacturing principles can improve business performance	<b>M1</b> Analyse the benefits of adopting lean manufacturing  <b>M2</b> Analyse the key challenges encountered when implementing lean manufacturing	
<b>LO2</b> Evaluate the Toyota Production System against the now more widely adopted generic approaches to lean manufacturing		<b>D2</b> Critically evaluate the Toyota Production System in comparison to a researched alternative, determining the elements that are critical in making the approach successful
<b>P2</b> Distinguish the principles of the Toyota Production System  <b>P3</b> Research alternative lean production system approaches  <b>P4</b> Examine the origins of lean and specify its early applications	<b>M3</b> Critically analyse alternative examples of lean production systems to determine the common principles, with reference to the Toyota Production System	



Pass	Merit	Distinction
<p><b>LO3</b> Specify a range of the process improvement tools used within lean manufacturing</p>		<p><b>D3</b> Make a supported and justified recommendation for a lean tool to be applied in addressing a specified process improvement</p>
<p><b>P5</b> Specify which tools are commonly associated with lean manufacturing and determine what context they would be applied in</p>	<p><b>M4</b> Evaluate how the most common lean tools can be applied to eliminate waste in a manufacturing process</p>	
<p><b>LO4</b> Demonstrate effective communication skills in order to lead the process of continuous improvement across an organisation</p>		<p><b>D4</b> Critically evaluate the importance of the skills required to successfully deploy change in an organisation</p>
<p><b>P6</b> Demonstrate and deliver a communication approach that can be taken to manage change in an organisation</p>	<p><b>M5</b> Evaluate the impact of this communication approach, including an evaluation of impact on employees and personal effectiveness</p>	

## 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*. McGraw-Hill.

WOMACK, J., JONES, D. and ROOS, D. (1990) *The Machine That Changed the World*. Free Press.

### Links

This unit links to the following related units:

*Unit 48: Manufacturing Systems Engineering*

*Unit 50: Advanced Manufacturing Technology*

*Unit 51: Sustainability*

# Unit 50: Advanced Manufacturing Technology

**Unit code** R/615/1518

**Unit level** 5

**Credit value** 15

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## Introduction

The ability of successful companies to meet the growing demand of customers is heavily influenced by the development of advanced manufacturing technologies. Customers expect high complexity products, on demand, and with a growing element of customisation. In adopting advanced manufacturing technologies, successful companies will ensure faster time to market of new products, improve products and processes, use new, sustainable, materials, and customise to customer requirements. Manufacturing systems engineering underpins this development.

In order to meet changing customer expectations and gain competitive advantage, focus needs to be applied to developing smart factories and advanced manufacturing technologies. Manufacturing organisations will seek integration between manufacturing technology, high performance computing, the internet, and the product at all stages of its life cycle.

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.

On successful completion of this unit students will be able to analyse and evaluate the potential of using advanced manufacturing technologies to improve the competitive advantage of the organisations adopting them. The student will develop knowledge and understanding of advanced manufacturing technologies, digitalisation and a range of advanced manufacturing technologies. They will also develop their own research activities into the latest developments.

## Learning Outcomes

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

1. Recognise a range of advanced manufacturing processes and cite examples of where they are most effective.
2. Analyse advanced manufacturing technologies to determine their appropriateness for an application or process.
3. Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies.
4. Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer.

## Essential Content

### LO1 **Recognise a range of advanced manufacturing processes to cite examples of where they are most effective**

#### *Manufacturing processes:*

Pressing and forming, casting and moulding, joining and soldering, mixing, final assembly, packaging, material handling, quality control/inspection

#### *Advanced manufacturing processes:*

Additive manufacturing technology (e.g. replacing forming, moulding, pressing), 3D printing, impact on rapid prototyping, availability of spares/obsolete parts, medical components available and customised

Mass customisation through 3D printing, opening up a self-serve market

Robotics/human interface and automation, high-precision technology and productivity e.g. aerospace, automotive, electronics assembly

#### *Types of application or industry:*

Industry examples: aerospace, automotive, healthcare, electronics, food and beverage, chemical and pharmaceutical, minerals, oil and gas, retail, fashion

Application examples: assembly, joining, moulding, soldering

### LO2 **Analyse advanced manufacturing technologies to determine their appropriateness for an application or process**

#### *Manufacturing technologies:*

High precision robotics and automation: healthcare (components and processes), aerospace, automotive, process control and visualisation through automation technology

Improvement in productivity through greater automation

Quality of manufacturing processes improved through integration of robotics

Examples of using 3D printing and other forms of additive manufacturing to produce medical equipment, spares parts for items that may have become obsolete, mass customisation; what the customer wants, when they want it

**LO3 Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies**

*Manufactured product:*

Research the traditional methods used to manufacture an existing product, determine the associated processes required to bring it to market and identify the limitations of these methods and processes

Explore how advanced manufacturing technology could be applied to produce this product and suggest how applying such processes would influence its production, costs, time to market and customer satisfaction (e.g. healthcare/medical such as hip joint, traditional method vs mass customisation and the possible use of 3D printing)

3D printing and its availability is opening up new markets, but also new business models for organisations; explore the future possibilities for self-serve/or self-production of items

**LO4 Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer**

*Next industrial revolution:*

Industry 4.0

Internet of Things: over time industry has transformed from being local-based to communication-based technology; the possibilities for connected technology and connected factories are ever increasing

Cyber-physical systems: collaborative robotics and highly integrated manufacturing systems

Mass customisation: there is a growing demand and desire for individual products. In 1908, referring to the Model T, Henry Ford said, "You can have any colour, as long as it's black." In 2015 you can have trillions of variations of the Ford F150; advanced manufacturing technology and the ability to manage complexity is key to that realisation

Digitalisation and increased automation; the ability to simulate and create a digital twin has the potential to dramatically reduce time to market

The drive to increase efficiency requires innovation and innovative technology; 25% of all energy used is required by industry alone

Big data; the development of an ever connected production environment alongside cloud computing presents a challenge of having a stream of production data and the need to analyse this in order to make timely informed decisions

## Learning Outcomes and Assessment Criteria

Pass		Merit	Distinction
<b>LO1</b> Recognise a range of advanced manufacturing processes to cite examples of where they are most effective			<b>D1</b> Research and evaluate a manufactured product and identify the technology used
<b>P1</b> Recognise a range of advanced manufacturing process or technologies and cite examples of where they are most effective	<b>M1</b> Compare a traditional manufacturer to one employing advanced manufacturing to discuss the fundamental differences		
<b>LO2</b> Analyse advanced manufacturing technologies to determine their appropriateness for an application or process			<b>D2</b> Examine the potential justification for an organisation to invest in advanced manufacturing technology
<b>P2</b> Analyse advanced manufacturing technologies to determine their appropriateness for an application or process	<b>M2</b> Explore how advanced manufacturing could be applied, and give examples of where technology would be suited		
<b>LO3</b> Analyse an existing manufactured product and associated process to introduce proposals for possible improvements based on the introduction of advanced manufacturing technologies			<b>D3</b> Critically evaluate the impact of utilising advanced manufacturing technology rather than the existing method on both the customer and the manufacturer
<b>P3</b> Analyse an existing manufactured product and identify the key technology used to produce the item	<b>M3</b> Evaluate the effectiveness of the current method and suggest an alternative advanced manufacturing technology		

Pass	Merit	Distinction
<p><b>LO4</b> Evaluate the concept of the next industrial revolution to determine the impact on both manufacturers and the consumer</p>		<p><b>D4</b> Investigate and justify the types of industry or product that would benefit most from an innovative advanced manufacturing approach</p>
<p><b>P4</b> Evaluate the concept of a 4th industrial revolution</p> <p><b>P5</b> Identify the key elements of Industry 4.0</p>	<p><b>M4</b> Evaluate the impact of advanced manufacturing on both manufacturers and the customer</p>	



## Recommended Resources

### Textbooks

LEFTERI, C. (2012) *Making It: Manufacturing Techniques for Product Design*. 2nd Ed. Laurence King.

WRIGHT, P.K. (2000) *21st Century Manufacturing*. New Jersey: Prentice-Hall Inc.

### Websites

<a href="https://www.gov.uk">https://www.gov.uk</a>	GOV.UK Future of manufacturing: a new era of opportunity and challenge for the UK (Report)
<a href="https://w3.siemens.com/">https://w3.siemens.com/</a>	Siemens The Future of Manufacturing (General Reference)
<a href="https://hvm.catapult.org.uk/">https://hvm.catapult.org.uk/</a>	Catapult High Value Manufacturing (General Reference)

### Links

This unit links to the following related units:

*Unit 48: Manufacturing Systems Engineering*

*Unit 49: Lean Manufacturing*

*Unit 51: Sustainability*

# Unit 51: Sustainability

<b>Unit code</b>	<b>Y/615/1519</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Living and working in the 21st century will bring a range of sustainability challenges that our society has not seen before. For many people on our planet key resources such as food, water and energy will be in short supply, whilst the effects of climate change will be felt by everyone.

The Brundtland Commission of the United Nations on 20th March 20th 1987 defined sustainability as: “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Engineers will be in the frontline of the battle to overcome the challenges of creating a sustainable economy, but no single discipline will have the capability to tackle the problems alone. Sustainability is a multidisciplinary challenge, and engineers of the future will have to work collaboratively with a whole range of other stakeholders, such as scientists, politicians and financiers, if they are to be able to produce the practical and technological solutions required within the necessarily urgent time scales.

This unit is designed to support the Professional Engineering and Professional Engineering Management core units at Level 4 and 5. On successful completion of this unit the student will possess a wide range of knowledge and understanding of the issues and topics associated with sustainability and low carbon engineering.

## **Learning Outcomes**

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

1. Determine the nature and scope of the technical challenges of ensuring sustainable development.
2. Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems.
3. Evaluate the use of alternative energy generation techniques in relation to their contribution to a low carbon economy.
4. Analyse a variety of data sources to estimate the carbon footprint of a socio-technical scenario.

## Essential Content

### LO1 **Determine the nature and scope of the technical challenges of ensuring sustainable development**

*The scope and social context of sustainability:*

Sustainable development

Brundtland definition

Global demographics, trends and predictions

Population growth

Standard of living, actual and expected

Urbanisation and the balance of urban/rural space

Sustainable design

*Environmental issues:*

Climate change, planetary energy balance, carbon cycle science, the 2<sup>0</sup> C climate change obligation

Carbon capture and sequestration

Pollution, pollution prevention and management

Carbon trading

Eco-systems and habitat

*Resources:*

Food, water, energy and raw materials

### LO2 **Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems**

*Systems thinking and socio-technical systems:*

The politics and economics of sustainability

Kyoto Protocol

UN Climate Change Conference (COP)

European Union Emissions Trading Scheme

*Sustainable infrastructures:*

Low carbon transport systems  
Sustainable cities  
Green building  
Power storage and distribution  
Sustainable logistics  
Waste and recycling

**LO3 Evaluate the use of alternative energy generation techniques in relationship to their contribution to a low carbon economy**

*Alternative energy resources:*

Nuclear, solar, wind, tidal and wave, geothermal, biomass and bioenergy  
Whole life cycle costing  
Precautionary principle

**LO4 Analyse a variety of data sources to estimate the carbon footprint of a socio-technical scenario**

*Types of carbon footprint:*

Organisational  
Value chain  
Product  
Carbon footprint science  
Calculation methodologies: direct and indirect  
System boundaries  
Case study examples

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Determine the nature and scope of the technical challenges of ensuring sustainable development		<b>D1</b> Critically analyse how the interrelationship between the three key areas of technical challenges can be managed systemically to ensure maximum sustainability
<b>P1</b> Determine the nature and scope of the technical challenges of ensuring sustainable development, considering environmental, resource and demand issues	<b>M1</b> Review existing sustainable development plans to identify the way technical challenges are met and overcome	
<b>LO2</b> Articulate the importance of collaborating with other disciplines in developing technical solutions to sustainability problems		<b>D2</b> Critically analyse how a systemic approach can be used to support interdisciplinary collaboration in developing sustainable infrastructures
<b>P2</b> Articulate the interdisciplinary issues associated with the construction of sustainable infrastructures, with attention to the competing pressures within these infrastructures	<b>M2</b> Analyse how political and economic issues can impact upon technical solutions	

Pass	Merit	Distinction
<b>L03</b> Evaluate the use of alternative energy generation techniques in relation to their contribution to a low carbon economy		<b>D3</b> Critically analyse the selection of alternative energy generation techniques for a low carbon economy within the wider socio-technical sustainability agenda
<b>P3</b> Evaluate the issues that need to be considered when selecting alternative low carbon energy sources	<b>M3</b> Analyse the difficulties in the evaluation and selection of alternative energy generation techniques for a low carbon economy	
<b>L04</b> Analyse a variety of data sources to estimate the carbon footprint of a socio-technical scenario		<b>D4</b> Analyse the alternative types and methods available for calculating the carbon footprint of a sociotechnical scenario, and make justified recommendations, selecting a best-fit method for effective comparison of systems
<p><b>P4</b> Evaluate a variety of data sources to estimate the carbon footprint of a number of socio-technical scenarios</p> <p><b>P5</b> Describe the process of calculating a carbon footprint</p>	<b>M4</b> Apply appropriate data from a range of options to calculate the carbon footprint of a socio-technical scenario	

## Recommended Resources

### Textbooks

BERNERS-LEE, M. (2019) *There Is No Planet B: A Handbook for the Make or Break Years* Cambridge University Press

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

BOYLE, G. (2012) *Energy Systems and Sustainability: Power for a Sustainable Future.* Oxford University Press.

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

HELM, D. (2015) *The Carbon Crunch: Why we are Getting Climate Change Wrong and How to Fix It.* Yale University Press.

HONE, D. (2014) *Putting The Genie Back: 2<sup>0</sup>c Will Be Harder Than We Think.* Whitefox Publishing.

### Websites

<http://www.carbontrust.com>

Carbon Trust  
Carbon foot printing  
(General Reference)

<http://www.fern.org/>

FERN  
Trading Carbon How it Works and Why it is  
Controversial  
(Ebook)

<https://www.populationinstitute.org>

Population Institute  
Demographic Vulnerability report (Report)

<http://www.un.org/>

United Nations  
Integrating Population Issues into  
Sustainable Development  
(Report)

<http://www.unwater.org/>

United Nations Water  
Annual World Water Development Report  
(Report)

<https://sustainabledevelopment.un.org/>

United Nations Sustainable Development  
Knowledge Platform  
(General Reference)



## **Links**

This unit links to the following related units:

*Unit 4: Managing a Professional Engineering Project*

*Unit 35: Professional Engineering Management*

# Unit 52: Further Electrical, Electronic and Digital Principles

<b>Unit code</b>	<b>L/615/1520</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Almost every aspect of our lives relies on electrical powered, electronically controlled machines and devices, many of them digital in format. To properly understand how to make the most efficient use of these devices in a safe and economical way, it is vital to have a thorough knowledge of the underlying principles on which they rely.

This unit builds on the preliminary techniques and skills introduced in *Unit 19: Electrical, Electronic and Unit 20: Digital Principles*.

The emphasis in this unit will be in developing a structured approach to the analysis of AC single-phase and three-phase powered circuitry. This will help students to arrive at the solution in the most efficient way, with the greatest probability of it being correct. In addition, students will be introduced to the expanding use of computers, using specialised software to solve electrical, electronic and digital circuits. This will allow students to develop the necessary confidence and competence in the four key areas of mathematical techniques, circuit analysis, circuit simulation and laboratory practice.

Successful completion of this unit will enable students to cope with increasingly complex problems and prepare them for the challenge of Level 6 academic programmes.

## **Learning Outcomes**

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

1. Use appropriate mathematical techniques to solve a range of electrical and electronic problems.
2. Apply appropriate circuit theorems to solve problems in electrical networks.
3. Use appropriate laboratory and computer simulation techniques to investigate both analogue and digital circuits and interpret the results.
4. Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions.

## Essential Content

### LO1 Use appropriate mathematical techniques to solve a range of electrical and electronic problems

#### *Formal steady state circuit analysis:*

Determinants, mesh analysis and nodal analysis (and their comparison)

Analysis using ideal sources, superposition theorem

#### *AC circuit analysis:*

Complex notation, polar and Cartesian coordinates, RLC circuits

Advanced use of phasor diagrams

Power: instantaneous power, power factor, apparent power, the power triangle

### LO2 Apply appropriate circuit theorems to solve problems in electrical networks

#### *Three-phase theory:*

Application of trigonometric methods to solution of phasor diagrams

Application of complex numbers to represent quantities in AC circuits

Single-phase representation

Solution of balanced three-phase circuits

Complex notation applied to three-phase, unbalanced loads, unconnected neutral point

Power, reactive power and power factor correction for three-phase systems

**LO3 Use appropriate laboratory and computer simulation techniques to investigate both analogue and digital circuits and interpret the results**

*ECAD:*

Use of computer modelling and simulation techniques to analyse and solve electronic, electrical and digital circuits, such as filters and amplifiers using operational amplifiers and discrete devices; digital logic circuit elements; and simple combination and sequential circuits

**LO4 Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions**

*Non-linear circuits:*

Characteristics of linear and non-linear circuits, mathematical modelling of a number of semiconductor devices, including diodes, bipolar and Field Effect Transistors and how this can be used to predict their 'real' behaviour in practice

Mathematically modelling the behaviour of semiconductor diodes, bipolar transistors and Field Effect Transistors

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Use appropriate mathematical techniques to solve a range of electrical and electronic problems		<b>D1</b> Apply an accurate approach to problem solving with clear justification of methods used with a high standard of explanation for each method
<b>P1</b> Produce basic solutions to electrical and electronic problems to a satisfactory standard, but with some misunderstandings	<b>M1</b> Provide reasoned solutions to problems, showing a logical approach and using a range of mathematical methods	
<b>L02</b> Apply appropriate circuit theorems to solve problems in electrical networks		<b>D2</b> Evaluate electrical theory by using a variety of mathematical and other methods to produce accurate solutions with clear justification of the methods used
<b>P2</b> Use electrical network theory to provide solutions to problems to a satisfactory standard, with some level of ambiguity and errors	<b>M2</b> Apply electrical network theory and provide accurate solutions to problems, showing a logical approach	
<b>L03</b> Use appropriate laboratory and computer simulation techniques to investigate both analogue and digital circuits and interpret the results		<b>D3</b> Present a clear evaluation of the operation of current analogue and digital logic circuits by comparing their predicted behaviour with the simulated, theoretical and practical results
<b>P3</b> Use appropriate laboratory and computer simulation techniques to explain the performance of digital logic circuits and analogue circuits	<b>M3</b> Explore analogue and digital logic circuits to show a structured approach to the solutions of problems using a variety of methods	

Pass	Merit	Distinction
<b>LO4</b> Explain the characteristics of non-linear circuits to predict their behaviour under a variety of conditions		<b>D4</b> Evaluate the application of theory, simulation and practical investigation of a number of circuits using nonlinear circuits
<b>P4</b> Describe the characteristics of non-linear circuits and how their behaviour differs in practice with 'ideal' devices	<b>M4</b> Investigate a variety of non-linear circuits by calculating the effects of non-linear behaviour in a number of differing circuits	

## Recommended Resources

### Textbooks

- BIRD, J. (2013) *Electrical Circuit Theory and Technology*. Routledge.
- HUGHES, E. et al. (2012) *Electrical and Electronic Technology*. Pearson.
- REHG, J.A. and SARTORI, G.J. (2005) *Industrial Electronics*. Prentice-Hall.
- WILAMOWSKI, B.M. and IRWIN, J.D. (2011) *The Industrial Electronic Handbook: Fundamentals of Industrial Electronics*. CRC Press.

### Websites

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|---|---|
| <a href="http://www.bath.ac.uk/">http://www.bath.ac.uk/</a>                     | University of Bath<br>Patents<br>(General Reference)                                  |
| <a href="http://www.bsigroup.com">http://www.bsigroup.com</a>                   | British Standards Institution<br>Standards<br>(General Reference)                     |
| <a href="https://www.ieee.org">https://www.ieee.org</a>                         | Institute of Electrical and Electronics Engineers<br>Standards<br>(General Reference) |
| <a href="https://app.knovel.com/">https://app.knovel.com/</a>                   | Knovel<br>(Research)  |
| <a href="https://www.esdu.com">https://www.esdu.com</a>                         | Engineering Science Data Unit<br>(General Reference)                                  |
| <a href="http://www.theiet.org/">http://www.theiet.org/</a>                     | Institute of Engineering and Technology<br>(General Reference)                        |
| <a href="http://www.theiet.org/">http://www.theiet.org/</a>                     | Institute of Engineering and Technology<br>(Journal)                                  |
| <a href="http://www.newelectronics.co.uk/">http://www.newelectronics.co.uk/</a> | New Electronics Digital<br>Magazine<br>(Journal)                                      |



<a href="http://www.electronicsworld.co.uk/">http://www.electronicsworld.co.uk/</a>	Electronics World Magazine (Journal)
<a href="http://tie.ieee-ies.org/">http://tie.ieee-ies.org/</a>	Industrial Economics Society (Journal)
<a href="http://www.epemag.com/">http://www.epemag.com/</a>	Everyday Practical Electronics Magazine (Journal)

## **Links**

This unit links to the following related units:

*Unit 19: Electrical and Electronic Principles*

*Unit 20: Digital Principles*

## Unit 53:

## Utilisation of Electrical Power

<b>Unit code</b>	<b>R/615/1521</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

The supply, processing and usage of electrical energy is a leading preoccupation around the world today, with significant technical, economic, environmental and societal implications. Engineers have to engage seriously with this issue and need to be aware of the real and practical impact of their decisions.

The aim of this unit is to develop students' understanding of electrical power systems and power distribution, giving consideration to the advantages and disadvantages of alternative power sources.

Students will learn about the construction and characteristics of power transmission and distribution systems, including the interconnections of systems and their necessary protection. Students will also consider the economics of components, power systems and alternative energy sources, in line with emerging developments within the energy sector.

On successful completion of this unit students will be able to explain the demands, sources and construction of electrical power generation and distribution systems, review the interconnections of power systems and their necessary protection, identify the requirement for engineering activity and describe new and emerging methods to optimise energy usage.

## Learning Outcomes

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

1. Examine the demands, sources and construction of electrical power generation and distribution systems.
2. Explore the interconnections of power systems and their protection to explain the critical processes and the effects of failure and the importance of electrical safety.
3. Evaluate the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources.
4. Discuss new and emerging methods to optimise energy usage, conversion and storage techniques.

## Essential Content

### LO1 **Examine the demands, sources and construction of electrical power generation and distribution systems**

*Demands of a power generation and transmission system:*

Total power demands of a defined country over a period of a working week, identifying average, minimum and maximum demands

Overall annual energy consumption of domestic, industrial, transport and other systems, identifying and quantifying energy losses

Extent of delivered energy that is in the form of electrical energy

Comparison between the demands of a G20 industrial economy with that of a Third World economy; analysis of the trends of energy supply and demand data to predict future energy requirements and budgets

Identification of the contribution to the energy supplied by each of the significant primary sources of energy of a defined country. Influence of long-term governmental policy on managing the energy budget

### LO2 **Explore the interconnections of power systems and their protection to explain the critical processes and the effects of failure and the importance of electrical safety**

*Construction of power generation and transmission systems:*

Comparisons between the distribution of power using DC and single-phase and polyphase AC transmission systems, amplitude and phase of voltages and currents in three-phase systems with resistive and complex loads

Power factor and power measurement techniques of AC systems, including identification of a range of loads and their respective power factors, consequences of loads with poor power factor and the advantages of applying power factor corrections

Calculation of power factor correction components

Recognition of the effects of perturbations and harmonics within AC systems and describing methods to measure and reduce harmonics

The need to protect the power distribution network from the effects of overload or damage, and identification of the requirements of a robust protection system

Evaluation of the impedance of an AC transmission line, its power losses and its effect on the power delivered to a load

Review safety procedures associated with power networks and techniques for the safe measurement of system parameters

Analysis of a power network with multiple generators, transmission lines and loads using power systems simulation software

**LO3 Evaluate the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources**

*Sources of electrical energy:*

Efficiency, costs, security and environmental implications of energy production using coal, oil and natural gas

Definition of 'renewable' in relation to sources of energy

Evaluation of the efficiency, costs, security and environmental implications of energy production using renewable sources of mechanical kinetic energy, including wave, tidal, large- and small-scale hydro and wind

Evaluate the efficiency, costs, security and environmental implications of energy production using solar heating, solar photovoltaics, biomass, fuel cells and geothermal techniques. Current state of research into nuclear, fusion and fission energy and other novel forms of energy

**LO4 Discuss new and emerging methods to optimise energy usage, conversion and storage techniques**

*Techniques for optimising electrical energy generation:*

Techniques for optimising the generation of electricity in power stations and small-scale generators by using varied and distributed generation systems and managing the generation of power

*Techniques for optimising energy usage and conversion:*

Evaluating technologies and techniques for improving the efficiency or reducing the energy consumption of equipment in common use, including lighting, heating, transport and industrial processes

*Energy storage techniques:*

The need for energy storage techniques as part of an energy management programme, characteristics of short-term and long-term energy storage techniques and their connection to the power grid, including, hydro, battery, super capacitor, flywheel and thermal

Emerging battery technologies and battery management techniques

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Examine the demands, sources and construction of electrical power generation and distribution systems		<b>D1</b> Critically evaluate governmental policies for managing energy budgets in the long term, making justified recommendations
<b>P1</b> Examine the key aspects of a country's energy supply, demand and losses to create a balanced energy budget for the example	<b>M1</b> Apply reliable data to quantify past and current energy trends and predict future trends, having first established the reliability of data from a variety of sources	
<b>L02</b> Explore the interconnections of power systems and their protection to explain the critical processes and the effects of failure and the importance of electrical safety		<b>D2</b> Critically evaluate the technologies for maintaining a high quality electrical supply to customers and demonstrate the advantages of applying these by computer simulation or otherwise
<b>P2</b> Explore the key aspects of three-phase power systems using distributed generators and loads and protection <b>P3</b> Perform calculations and simulations on example systems, showing power losses and the advantages of applying power factor correction	<b>M2</b> Analyse and interpret the results of computer-based simulations of power networks	

Pass	Merit	Distinction
<p><b>L03</b> Evaluate the effectiveness of forms of engineering activity to promote sustainable development, with consideration of the economics of components, power systems and alternative energy sources</p>		<p><b>D3</b> Critically evaluate novel forms of energy generation using recent, peer-reviewed</p>
<p><b>P4</b> Evaluate the technology of renewable sources of energy, taking into account efficiency, costs, security and environmental implications</p>	<p><b>M3</b> Illustrate the application of renewable energy sources to meet existing demands, taking into account efficiency, costs, security and environmental implications</p>	<p>publications, taking into account efficiency, costs, security and environmental implications</p>
<p><b>L04</b> Discuss new and emerging methods to optimise energy usage, conversion and storage techniques</p>		<p><b>D4</b> Critically evaluate novel forms of energy optimisation and</p>
<p><b>P5</b> Discuss representative examples of existing and emerging methods of energy optimisation</p>	<p><b>M4</b> Evaluate the environmental effects of applying known energy optimisation techniques</p>	<p>efficiency and their applications using recent, peer-reviewed publications</p>

## Recommended Resources

### Textbooks

BAYLIS, C. and HARDY, B. (2012) *Transmission and Distribution Electrical Engineering*. Elsevier Science and Technology. Newnes.

BREEZE, P.A. (2014) *Power Generation Technologies*. 2nd Ed. Newnes.

### Links

This unit links to the following related units:

*Unit 41: Distributed Control Systems*

*Unit 44: Industrial Power, Electronics and Storage*



# Unit 54: Further Control Systems Engineering

**Unit code** Y/615/1522

**Unit level** 5

**Credit value** 15

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## Introduction

Control engineering is usually found at the top level of large projects in determining the engineering system performance specifications, the required interfaces, and hardware and software requirements. In most industries, stricter requirements for product quality, energy efficiency, pollution level controls and the general drive for improved performance, place tighter limits on control systems.

A reliable and high performance control system depends a great deal upon accurate measurements obtained from a range of transducers, mechanical, electrical, optical and, in some cases, chemical. The information provided is often converted into digital signals on which the control system acts to maintain optimum performance of the process.

The aim of this unit is to provide the student with the fundamental knowledge of the principles of control systems and the basic understanding of how these principles can be used to model and analyse simple control systems found in industry. The study of control engineering is essential for most engineering disciplines, including electrical, mechanical, chemical, aerospace, and manufacturing.

On successful completion of this unit students will be able to devise a typical three-term controller for optimum performance, grasp fundamental control techniques and how these can be used to predict and control the behaviour of a range of engineering processes in a practical way.

## **Learning Outcomes**

1. Discuss the basic concepts of control systems and their contemporary applications.
2. Analyse the elements of a typical, high-level control system and its model development.
3. Analyse the structure and behaviour of typical control systems.
4. Explain the application of control parameters to produce optimum performance of a control system.

## Essential Content

### LO1 **Examine the basic concepts of control systems and their contemporary applications**

*Background, terminology, underpinning principles and system basics:*

Brief history of control systems and their industrial relevance, control system terminology and identification, including plant, process, system, disturbances, inputs and outputs, initial time, additivity, homogeneity, linearity and stability

Basic control systems properties and configurations, classification and performance criteria of control systems

Block diagram representation of simple control systems and their relevance in industrial application

Principles of Transfer Function (TF) for open and closed loop systems, use of current computational tools for use in control systems (e.g. Matlab, Simulink, Labview)

### LO2 **Explore the elements of a typical, high-level control system and its model development**

*Developing system applications:*

Simple mathematical models of electrical, mechanical and electro-mechanical systems

Block diagram representation of simple control systems

Introduction of Laplace transform and its properties, simple first and second order systems and their dynamic responses

Modelling and simulation of simple first and second order control system using current computational tool (e.g. Matlab/Simulink)

### LO3 **Analyse the structure and behaviour of typical control systems**

#### *System behaviour:*

Transient and steady behaviour of simple open loop and closed loop control systems in response to a unit step input

Practical closed loop control systems and the effect of external disturbances

Poles and zeros and their role in the stability of control systems, steady-state error. Applicability of Routh-Hurwitz stability criterion

Use of current computational tools (e.g. Matlab, Simulink) to model, simulate and analyse the dynamic behaviour of simple open and closed loop control systems

### LO4 **Explain the application of control parameters to produce optimum performance of a control system**

#### *Control parameters and optimum performance:*

Introduction to the three-term PID controller, the role of a Proportional controller (P), Integral controller (I) and the Derivative controller (D)

General block diagram representation and analysis, effects of each term, P-I-D, on first and second order systems

Simple closed loop analysis of the different combinations of the terms in PID controllers, effect of the three terms on disturbance signals and an introduction to simple PID controller tuning methods

Modelling and simulation using current computational tools (e.g. Matlab, Simulink, Labview) to analyse the effects of each P-I-D term, individually and in combination on a control system

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Examine the basic concepts of control systems and their contemporary applications		<b>D1</b> Evaluate the performance of a PID controller to demonstrate basic control system techniques
<b>P1</b> Examine the basic concepts of control systems using block diagram representation and simplifications  <b>P2</b> Model simple open and closed loop control systems simulation software	<b>M1</b> Apply advanced modelling techniques using commercially available control software  <b>M2</b> Develop the block diagram of a closed loop system for the position control of DC motor using a PID controller	
<b>LO2</b> Explore the elements of a typical, high-level control system and its model development		<b>D2</b> Perform high-level self-tuning control system techniques using mathematical modelling and computer simulation
<b>P3</b> Explore the main building blocks for high-level electrical and mechanical control systems  <b>P4</b> Apply Laplace transforms to basic mechanical or electrical control problems	<b>M3</b> Analyse Electrical, Mechanical and Electro-Mechanical control systems using appropriate mathematical models and computer simulation	

Pass	Merit	Distinction
<b>L03</b> Analyse the structure and behaviour of typical control systems		<b>D3</b> Analyse the performance of an electro-mechanical control system when subjected to external disturbances
<b>P5</b> Analyse the behaviour and response of first and second order systems  <b>P6</b> Analyse the external effects on the stability of PID control systems and the techniques used to maintain stability in these systems	<b>M4</b> Evaluate using analytical techniques how the stability of a dynamic PID control system is maintained	
<b>L04</b> Examine the application of control parameters to produce optimum performance of a control system		<b>D4</b> Analyse the behaviour of a control system when P, I, D terms are changed individually and in combination using modelling and computer simulation techniques
<b>P7</b> Examine the role and implementation of the PID controllers in a simple electrical and mechanical control system  <b>P8</b> Examine the effects of the P, I, and D parameters on the dynamic responses of the first and second order systems	<b>M5</b> Analyse dynamic responses of PID controllers in terms of position control, tracking and disturbance rejection	

## Recommended Resources

### Textbooks

DABNEY, J.B. and HARMAN, T.L. (2003) *Mastering Simulink*. Prentice Hall.

DORF, R.C. and BISHOP, R.H. (2014) *Modern Control Systems*. 12th Ed. Pearson.

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

### Links

This unit links to the following related units:

*Unit 41: Distributed Control Systems*

*Unit 16: Instrumentation and Control Systems*

# Unit 62: Heating, Ventilation and Air Conditioning (HVAC)

<b>Unit code</b>	<b>H/615/1524</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

The buildings we use in everyday life to live, work, study and socialise are becoming increasingly more complex in their design. As well as being subject to more stringent environmental emission targets, within these buildings the heating, ventilation and air conditioning (HVAC) systems play a vital role in maintaining the comfort of the occupants within the built environment.

This unit will introduce students to some of the most important HVAC systems and their supporting elements, and the underpinning science that is currently used in many different buildings around the world.

Subjects covered include: ventilation rates, systems, legislation, strategies and associated equipment. Also explored are topics such as air conditioning systems, cooling loads, psychrometric principles and processes, heating systems, fuels, combustion processes, boiler efficiency calculations and Building Management Systems (BMS).

On successful completion of this unit students will be able to explain the fundamental principles of HVAC systems and discuss the operational advantages of using BMS for maintaining the careful balance between ergonomic climate control and maximum economic efficiency.



## **Learning Outcomes**

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

1. Explain the operating principles of non-domestic ventilation systems.
2. Explore the range of air conditioning systems.
3. Investigate the operational characteristics of non-domestic heating systems.
4. Describe the role Building Management Systems (BMS) have in controlling and monitoring HVAC systems.

## Essential Content

### LO1 Explain the operating principles of non-domestic ventilation systems

#### *Ventilation systems:*

Ventilation requirements: approved documents, requirements for occupants or processes

Ventilation strategies: local or centralised systems, natural ventilation, extract only, supply only and balanced systems

Ventilation system components and typical system layouts

#### *Ventilation rates:*

Calculation of ventilation rates, supply for occupants or processes, supply to achieve required room air change rate

Mass and volumetric flow rates to maintain design room conditions

#### *Fans:*

Fan types and operational characteristics

Fan selection and Fan Laws

### LO2 Explore the range of air conditioning systems

#### *Air conditioning systems:*

Air conditioning requirements: requirement for comfort cooling or close control

Air conditioning strategies: types of air conditioning plant

#### *Cooling loads:*

Estimation of heat gains and cooling loads

Factors affecting the cooling load requirements, building/room use, shading, building construction and orientation, internal heat gains

#### *Psychrometrics:*

Psychrometric principles: psychrometric terms and properties

Plotting psychrometric processes using charts

Use of psychrometric charts to determine cooling coil, heater battery, frost coil and humidifier duties

### **LO3 Investigate the operational characteristics of non-domestic heating systems**

#### *Heating systems:*

Heating requirements: approved documents, occupant's comfort

Heat loss calculations: heat losses through a structure, U values and their use in calculating heating load requirements

Heating strategies: local or centralised systems

Heating system components and typical system layouts

#### *Fuels:*

Properties and characteristics of common solid, liquid and gaseous fuels

#### *Combustion:*

Combustion principles

Products of complete and incomplete combustion and their implications

Minimum air requirements for stoichiometric combustion

Causes of incomplete combustion

#### *Boiler efficiency:*

Boiler efficiency calculations

### **LO4 Describe the role Building Management Systems (BMS) have in controlling and monitoring HVAC systems**

#### *Requirement of the BMS:*

Client/end user requirements and operational needs, energy efficiency concerns

#### *Function of a BMS:*

Systems controlled by BMS: heating, lighting, ventilation, air conditioning, security/access

Energy monitoring and reporting

#### *BMS hardware:*

Types of BMS hardware available, advantages and disadvantages, performance and cost. Controlling software, remote access and control

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Explain the operating principles of non-domestic ventilation systems		<b>LO1 &amp; LO2</b> <b>D1</b> Evaluate and compare a number of passive and active methods used to help cool buildings giving suitable examples
<b>P1</b> Explain and compare two alternative ventilation strategies for a non-domestic building and recommend the most suitable  <b>P2</b> Using the information from P1, calculate the ventilation requirements for the rooms in a non-domestic building	<b>M1</b> Discuss the types of fans used in non-domestic ventilation systems and analyse their characteristics	
<b>LO2</b> Explore the range of air conditioning systems		
<b>P3</b> Explain the requirement for air conditioning in a variety of non-domestic buildings  <b>P4</b> Estimate the cooling load requirements for rooms in non-domestic buildings using a recognised 'rule of thumb' method	<b>M2</b> Analyse the factors affecting the cooling loads in buildings	

Pass	Merit	Distinction
<b>LO3</b> Investigate the operational characteristics of non-domestic heating systems		<b>LO3 &amp; LO4</b> <b>D2</b> Calculate the minimum air requirements for a given fuel and distinguish between complete and incomplete combustion, predicting the possible consequences of incomplete combustion
<b>P5</b> Explain and compare two alternative heating strategies for a non-domestic building and recommend the most suitable  <b>P6</b> Estimate the heating load requirements for rooms in non-domestic buildings using a recognised 'rule of thumb' method	<b>M3</b> Discuss the combustion properties of common fuels used in non-domestic heating systems	
<b>LO4</b> Describe the role Building Management Systems (BMS) have in controlling and monitoring HVAC systems		
<b>P7</b> Describe the requirements of a building management system in non-domestic buildings  <b>P8</b> Describe the functions performed by a building management system in a non-domestic building	<b>M4</b> Evaluate the advantages of a building fitted with a full Building Management System	

## Recommended Resources

### Textbooks

CHADDERTON, D. (2013) *Building Services Engineering*. 6th Ed. Abingdon: Routledge.

CIBSE. (2009) *CIBSE Guide H: Building control systems*. CIBSE, London.

HALL, F. and GREENO, R. (2009) *Building Services Handbook*. 5th Ed. Oxford: Elsevier.

## Unit 63:

## Industrial Services

<b>Unit code</b>	<b>K/615/1525</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

Behind the scenes in many modern-day manufacturing facilities there lies a complex system of services that powers production, both day and night. The underlying aim of this unit is to enhance the students' understanding of the electrical supply systems, industrial air compressors, steam services, refrigeration systems and heat pumps that are used in an array of industrial engineering environments.

This broad-based methodology reflects the fact that operations engineering encompasses many disciplines and, as such, engineers must be conversant in the wide scope of service provision. The intention is to encourage students to develop a holistic approach to the design, operation, installation and maintenance of both industrial services and operating equipment.

The student will be introduced to the fundamental principles of electrical power and lighting systems, the rudiments of industrial compressed air systems, the provision of steam for both power generation and process plant, and the applications and precepts of refrigeration plant and heat pumps.

On successful completion of this unit students will be able to manage and maintain a wide range of commonly encountered industrial systems.

### Learning Outcomes

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

1. Apply the operating principles of electrical power and lighting systems.
2. Investigate the applications and efficiency of industrial compressors.
3. Discuss provision of steam services for process and power use.
4. Review industrial refrigeration and heat pump systems.

## Essential Content

### LO1 **Apply the operating principles of electrical power and lighting systems**

#### *Electrical power:*

Construction, starting and speed control of polyphase induction motors

Three-phase transformers: construction, clock number and group, parallel operation

Electrical distribution: power system topologies, efficiency, power factor causes and correction, effect on cost of supplies, circuit protection

#### *Lighting systems:*

Lighting fundamentals: SI units, energy efficient circuit design and layout

### LO2 **Investigate the applications and efficiency of industrial compressors**

#### *Industrial compressors:*

Types and applications of industrial compressors

Role of intercoolers, dryers and air receivers

Efficiency and performance of air compressors

Hazards and faults: safety consideration and associated legislation

### LO3 **Discuss the provision of steam services for process and power use**

#### *Steam power plant:*

Use of tables and charts to analyse wet and dry saturated steam

Circuit diagrams showing steam raising plant

Process steam: enthalpy of evaporation, available energy

Overall plant efficiencies for process

Power steam: superheated steam, turbine efficiency, Rankine cycle, cooling towers

Overall plant efficiency for power

Efficiencies and improvements



## LO4 **Review industrial refrigeration and heat pump systems**

### *Heat pumps and refrigeration:*

Typical industrial heat pump and refrigeration systems

Application of the second law of thermodynamics

Reversed heat engines: reversed Carnot cycle

Vapour compression cycle

Refrigerant fluids: environmental impact

Refrigeration tables and charts (p-h diagrams)

Coefficient of performance for heat pumps and refrigerators

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Apply the operating principles of electrical power and lighting systems		<b>D1</b> Analyse the approaches available for reducing electrical energy consumption/costs in an industrial production facility
<p><b>P1</b> Illustrate the construction and modes of connection of three-phase transformers</p> <p><b>P2</b> Discuss the applications and operating characteristics of polyphase induction motors</p> <p><b>P3</b> Apply the principles of good lighting design to produce a lighting scheme for a given application</p>	<p><b>M1</b> Compare the economics of single-phase and three-phase distribution, and assess the methods of speed control applied to polyphase induction motors</p>	
<b>LO2</b> Investigate the applications and efficiency of industrial compressors		<b>D2</b> Stating any assumptions, provide an explanatory derivation of the volumetric efficiency formula for a reciprocating compressor
<p><b>P4</b> Compare three types of industrial compressor and identify justifiable applications for each</p> <p><b>P5</b> Review potential industrial compressor faults and hazards</p> <p><b>P6</b> Determine the performance characteristics of an industrial compressor</p>	<p><b>M2</b> Calculate the isothermal and polytropic work of a reciprocating compressor and thus deduce the isothermal efficiency. Explain any discrepancies</p>	

Pass	Merit	Distinction
<b>L03</b> Discuss the provision of steam services for process and power use		<b>D3</b> Evaluate the modifications made to the basic steam raising systems to improve their overall efficiency
<b>P7</b> Demonstrate the need for superheated steam in a power generating plant  <b>P8</b> Discuss the requirements for process steam and determine overall plant efficiencies for steam process and power systems	<b>M3</b> Illustrate why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world	
<b>L04</b> Review industrial refrigeration and heat pump systems		<b>D4</b> Conduct a cost-benefit analysis on the installation of a ground source heat pump on a smallholding. Present your findings in the form of academic poster/presentation
<b>P9</b> Discuss the operating principles of both heat pumps and industrial refrigeration systems  <b>P10</b> Calculate COP, heating effect and refrigeration effect of reversed heat engines, making use of refrigeration tables and pressure/enthalpy charts	<b>M4</b> Assess the limiting factors that impact on the economics of heat pumps  <b>M5</b> Discuss the apparent contradiction between refrigeration cycles and the second law	



# Unit 64: Thermofluids

<b>Unit code</b>	<b>M/615/1526</b>
<b>Unit level</b>	<b>5</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

In everyday life you are never too far away from some system or device that relies on both fluid mechanics and thermodynamics. From the water circulating in your home central heating radiators to the hydraulic door closer on the back of a fire door, the presence of thermofluids is constantly around us.

The aim of this unit is to provide a rational understanding of functional thermodynamics and fluid mechanics in common industrial applications. The unit promotes a problem-based approach to solving realistic work-related quandaries such as steam plant efficiency and fluid flow capacities.

Students will examine fundamental thermodynamic principles, steam and gas turbine systems and viscosity in fluids, along with static and dynamic fluid systems. Each element of the unit will identify a variety of engineering challenges and assess how problems are overcome in real-life industrial situations.

Additionally, students will develop their perceptions of industrial thermodynamic systems, particularly those involving steam and gas turbine power. In addition, they will consider the impact of energy transfer in engineering applications along with the characteristics of fluid flow in piping systems and numerous hydraulic devices, all of which are prevalent in typical manufacturing and process facilities.

## Learning Outcomes

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

1. Review industrial thermodynamic systems and their properties.
2. Examine the operation of practical steam and gas turbines plants.
3. Illustrate the properties of viscosity in fluids.
4. Analyse fluid systems and hydraulic machines.

## Essential Content

### LO1 Review industrial thermodynamic systems and their properties

*Thermodynamic systems:*

Power generation plant

Significance of first law of thermodynamics

Analysis of Non-Flow Energy Equation (NFEE) and Steady Flow Energy Equation (SFEE) systems

Application of thermodynamic property tables

Energy transfer systems employing polytropic processes (isothermal, adiabatic and isentropic)

Pressure/volume diagrams and the concept of work done: use of conventions

The application of the Gas Laws and polytropic laws for vapours and gases

### LO2 Examine the operation of practical steam and gas turbines plants

*Steam and gas turbine plant:*

Principles of operation of steam and gas turbine plants

Use of property diagrams to analyse plant

Characteristics of steam/gas turbine plant as used in energy supply

Energy-saving options adopted on steam plants operating on modified Rankine cycle

Performance characteristics of steam and gas power plant

Cycle efficiencies: turbine isentropic efficiencies and overall relative efficiency

### LO3 Illustrate the effects of viscosity in fluids

*Viscosity in fluids:*

Viscosity: shear stress, shear rate, dynamic viscosity, kinematic viscosity

Viscosity measurement: operating principles of viscosity measuring devices e.g. falling sphere, U-tube, rotational and orifice viscometers (such as Redwood)

Newtonian fluids and non-Newtonian fluids: pseudoplastic, Bingham plastic, Casson plastic and dilatant fluids

## LO4 **Analyse fluid systems and hydraulic machines**

### *Fluid systems:*

Characteristics of fluid flow: laminar and turbulent flow, Reynolds number

Friction factors: relative roughness of pipe, use of Moody diagrams

Head losses across various industrial pipe fittings and valves, use of Bernoulli's Equation and Darcy's Formula

### *Hydraulic machines:*

Turbines: Pelton wheel, Kaplan turbine, Francis wheel

Pumps: centrifugal, reciprocating

### *Analysis of systems:*

Dimensional analysis: verification of equations for torque, power and flow rate

Application of dimensional analysis to determine the characteristics of a scale model

Use of Buckingham Pi Theorem

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Review industrial thermodynamic systems and their properties		<b>D1</b> Analyse an operational industrial thermodynamic system in terms of work done
<p><b>P1</b> Discuss the operation of industrial thermodynamic systems and their properties</p> <p><b>P2</b> Describe the application of the first law of thermodynamics to industrial systems</p> <p><b>P3</b> Illustrate the relationships between system constants for a perfect gas</p>	<b>M1</b> Determine the index of compression in polytrophic processes	
<b>L02</b> Examine the operation of practical steam and gas turbines plants		<b>D2</b> Evaluate the modifications made to the basic Rankine cycle to improve the overall efficiency of steam power plants
<p><b>P4</b> Explain the principles of operation of steam turbine plant</p> <p><b>P5</b> Calculate overall steam turbine plant efficiencies by the use of charts and/or tables</p> <p><b>P6</b> Discuss the principles of operation of gas turbine plants</p>	<b>M2</b> Justify why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world	



Pass	Merit	Distinction
<b>LO3</b> Illustrate the effects of viscosity in fluids		<b>D3</b> Compare the results of a viscosity test on a Newtonian fluid with that which is given on a data sheet and explain any discrepancies
<p><b>P7</b> Illustrate the properties of viscosity in fluids</p> <p><b>P8</b> Explore three viscosity measurement techniques</p>	<b>M3</b> Evaluate the effects of shear force on Newtonian and non-Newtonian fluids	
<b>LO4</b> Analyse fluid systems and hydraulic machines		<b>D4</b> Evaluate the use of dimensionless analysis using the Buckingham Pi Theorem for a given industrial application
<p><b>P9</b> Examine the characteristics of fluid flow in industrial piping systems</p> <p><b>P10</b> Discuss the operational aspects of hydraulic machines</p> <p><b>P11</b> Apply dimensional analysis to fluid flow</p>	<b>M4</b> Review the significance of the Reynolds number on fluid flow in a given system	

## Recommended resources

### Textbooks

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

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

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

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

### Websites

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

<http://www.khanacademy.org> Khan Academy  
(Tutorials)

### Links

This unit links to the following related units:

*Unit 11: Fluid Mechanics*

*Unit 29: Electro, Pneumatic and Hydraulic Systems*

*Unit 13: Fundamentals of Thermodynamics and Heat Engines*

# Unit 73: Materials Engineering with Polymers

**Unit code** K/616/2556

**Unit level** 4

**Credit value** 15

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## 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; polyesters

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)

acrylonitrile 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

Pass	Merit	Distinction
<b>L01</b> Examine how the fundamental aspects of the molecular structure and morphology of polymers affect their processing and performance properties		<b>L01 &amp; L02</b> <b>D1</b> Justify the selection of a polymer material for a given engineering application through critical analysis of its structure and properties
<b>P1</b> Explain how the structure and morphology of different given polymer materials affect their processing and performance properties	<b>M1</b> Calculate the molar mass of a given polymer sample, commenting on the significance of the results to processing and performance properties	
<b>L02</b> Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application		
<b>P2</b> Use preliminary investigations and simple identification tests to distinguish between different types of polymer materials	<b>M2</b> Apply structural considerations to compare and contrast the properties and processability of these polymer materials	
<b>L03</b> Determine how to select, modify, compound or adapt polymer material systems for a specific engineering application		<b>L03 &amp; L04</b> <b>D2</b> Critically evaluate test results to justify selection of the most suitable additive or acceptable amount of recycled material in a given product
<b>P3</b> Identify the required properties for a specified engineering product	<b>M3</b> Re-examine data sheets to extend the range of selected materials by proposing a suitable modification to the base material	
<b>P4</b> Evaluate data sheets to select the most appropriate materials and processing techniques for the engineering product		



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

## 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: Wiley.
- LA MANTIA, F. (2002) *Handbook of Plastics Recycling*. Shrewsbury: Rapra Technology Limited.
- MCCRUM, N.G., BUCKLEY, C.P. and BUCKNALL, C.B. (2003) *Principles of Polymer Engineering*. 2nd Ed. Oxford: Oxford. Univ. Press.
- OSSWALD, T.A. and MENGES, G. (2012) *Material Science of Polymers for Engineers*. 3rd Ed. Munich: Hanser.
- YOUNG, R.J. and LOVELL, P.A. (2011) *Introduction to Polymers*. Boca Raton: CRC Press.

### Websites

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|--|--|
| <a href="http://www.bpf.co.uk">www.bpf.co.uk</a>                               | British Plastics Federation<br>(General reference)   |
| <a href="http://www.iom3.org/polymer-society">www.iom3.org/polymer-society</a> | The Polymer Society<br>(General reference)   |
| <a href="http://www.cia.org.uk">www.cia.org.uk</a>                             | Chemical Industries Association<br>(General reference)   |
| <a href="http://www.cogent-ssc.com">www.cogent-ssc.com</a>                     | Cogent – Sector Skills Council<br>(General reference)  |
| <a href="http://www.stemnet.org.uk">www.stemnet.org.uk</a>                     | Network for Science, Technology,<br>Engineering and Maths<br>Network Ambassadors Scheme<br>(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

# Unit 74: Polymer Manufacturing Processes

**Unit code** M/616/2557

**Unit level** 4

**Credit value** 15

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## Introduction

This unit is designed to develop students' knowledge and understanding of the main manufacturing processes and techniques that can be applied to a wide range of polymer materials for a variety of manufacturing applications.

It is essential for a manufacturing engineer who may lead the planning, operation and management of their company's manufacturing systems to have a broad underpinning knowledge of conventional polymer manufacturing processes. Polymer materials have the capacity and potential to be processed into a huge variety of shapes and forms for a wide range of applications.

The first outcome of this unit provides background knowledge of the main principles of polymer flow and heat transfer relevant to processing. The second and third outcomes give a detailed overview of the conventional manufacturing techniques of polymers (extrusion, blow moulding, thermoforming and injection moulding) considering relevant equipment and processing steps. The final outcome provides the context to inform selection of the most suitable method of processing for a given application.

## Learning Outcomes

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

1. Relate the fundamental principles of polymer flow and heat transfer to polymer processing
2. Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products
3. Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps
4. Determine from a design perspective the most suitable manufacturing process for a given engineering component or product.

## Essential Content

### LO1 **Relate the fundamental principles of polymer flow and heat transfer to polymer processing**

#### *Polymer melt behaviour*

Elongational flow

Shear flow

Shear stress and shear strain

Determination of apparent viscosity

Dependence of apparent viscosity on temperature and relative molecular mass

Shear thinning behaviour of polymers

Viscoelasticity of polymer melt

Die swell

Flow in a capillary tube (equations for stress and shear rate)

Melt flow index test (MFI)

#### *Effect of heating and heat transfer in polymers*

Temperature-dependent behaviour of polymers

Conduction (heat conduction equation, thermal conductivity, thermal diffusivity)  
convection

Radiation

Comparison of heat transfer properties of polymers to other competitive materials e.g. Metals, ceramics, wood

### LO2 **Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products**

#### *Overview of processing techniques for thermoplastics*

Extrusion e.g. Sheet production, pipe production, blown film, wire and cable coating, co-extrusion

Injection moulding, injection blow moulding

Rotational moulding

Thermoforming

Consideration of materials and products

*Overview of processing techniques for thermosets:*

E.g. Compression moulding and injection moulding

Specific requirements to process thermosets

Consideration of materials and products

*Overview of shaping and processing techniques for rubber and elastomers:*

E.g. Extrusion, compression moulding and injection moulding

Compounding principle

Consideration of materials and products

**LO3 Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps**

*Extrusion*

The principle of the extrusion process

Extrusion line

Main components of extruder and their functions e.g. Hopper, screw, motor and gearing, breaker plate and screen pack, die, temperature control system

Single and twin-screw extruders

Die design and processing faults

*Injection moulding*

The principle of the injection moulding process

Components of injection moulding machine and their functions e.g. Clamping unit, injection unit, mould, machine bed and control unit

Process sequence

Common injection moulding faults and remedies

*Thermoforming*

The principle of the thermoforming process

Process components e.g. Clamp frame, heating systems, moulds

Selected thermoforming methods e.g. Female mould forming, male mould forming, plug assist forming, prestretch forming

Wall thickness and molecular orientation in thermoformed products

**LO4 Determine from a design perspective the most suitable manufacturing process for a given engineering component or product**

*Design consideration and application development process*

Identifying the end-use requirements after considering the product functions

Part geometry e.g shape, size, tolerances

Material selection

Flow analysis and the significant implications of process selection stage

Prototyping and testing

*Design for mouldability*

E.g. Viscosity, melt temperature, shrinkage, cooling requirements, selection of optimum processing conditions

*Tooling consideration*

Design for appearance e.g. Preventing weld lines, gate marks in injection moulded components

Design for precision e.g. Gate location, gate type, gate size, die design, cooling lines

*Consideration of production volumes and cost of manufacturing*

Relevant case studies

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Relate the fundamental principles of polymer flow and heat transfer to polymer processing		<b>LO1 &amp; LO2</b> <b>D1</b> Critically evaluate the effect of temperature and relative molecular mass on viscosity and hence, processing
<b>P1</b> Explain the differences between the types of flow apparent in polymer melt and their relevance to processing <b>P2</b> Explain the difference in heat transfer between polymers and alternative materials and the effect it has on processing	<b>M1</b> Calculate polymer flow and heat transfer parameters for different grades of a thermoplastic material, commenting on the significance of the results for polymer processing	
<b>LO2</b> Illustrate the variety of polymer processing and shaping techniques available to manufacture a wide range of engineering components and products		
<b>P3</b> Describe a manufacturing set-up for given products and materials	<b>M2</b> Compare and contrast a range of alternative processing and shaping techniques for a given product/application	
<b>LO3</b> Describe the main technical components of commonly used polymer processing equipment, their functions and the main operational steps		<b>D2</b> Justify the most suitable manufacturing process for a given engineering product
<b>P4</b> Define the main differences between extrusion, injection moulding and thermoforming in terms of their components, functions and process sequence	<b>M3</b> Analyse potential process-related faults for a given product or application	
<b>LO4</b> Determine from a design perspective the most suitable manufacturing process for a given engineering component or product		<b>D3</b> Critically evaluate the cost effectiveness of the selected manufacturing process
<b>P5</b> Determine functions, shape and material for a given component/product and recommend the most appropriate manufacturing process based on the component's or product's functions, shape and material	<b>M4</b> Justify specific tooling for a given component or product	



## Recommended Resources

### Textbooks

BAIRD, D.G. and COLLIAS, D.I. (2014) *Polymer Processing: Principles and Design*. 2nd Ed. New Jersey: Wiley.

LEE, N.C. (2007) *Understanding Blow Molding*. 2nd Ed. Munich: Hanser.

OSSWALD, T.A. (2011) *Understanding Polymer Processing: Processes and Governing Equations*. Munich: Hanser Publishers.

RAO, N.S. and SCHUMACHER, G. (2004) *Design Formulas for Plastics Engineers*. Munich: Hanser.

RAUWENDAAL, C. (2014) *Polymer Extrusion*. 5th Ed. Munich: Hanser Publications.

THRONE, J.L. (2008) *Understanding Thermoforming*. 2nd Ed. Munich: Hanser.

### Websites

[www.bpf.co.uk](http://www.bpf.co.uk)

British Plastics Federation  
(General reference)

[www.iom3.org/polymer-society](http://www.iom3.org/polymer-society)

The Polymer Society  
(General reference)

[www.cia.org.uk](http://www.cia.org.uk)

Chemical Industries Association  
(General reference)

[www.cogent-ssc.com](http://www.cogent-ssc.com)

Cogent – Sector Skills Council

[www.stemnet.org.uk](http://www.stemnet.org.uk)

(General reference)

Network for Science, Technology,  
Engineering and Maths – Network  
Ambassadors Scheme

### Essential Resources

Laboratory Micro Injection Moulder Filament Extrusion line

Vacuum former

Melt Flow tester

Laboratory balance

## Unit 75:

## Industry 4.0

<b>Unit code</b>	<b>F/617/3949</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### 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
<b>L01</b> Investigate the factors leading to the fourth industrial revolution and the characteristics of a smart factory		<b>D1</b> Evaluate the socio-economic impact of industrial revolutions and the global response to Industry 4.0
<b>P1</b> Investigate the key milestones of industrial revolutions leading to the smart factory  <b>P2</b> Describe the characteristics of an Industry 4.0 compliant smart factory	<b>M1</b> Analyse the key historical factors that have contributed to industrial revolutions leading to Industry 4.0 compliant smart factories	
<b>L02</b> Review the range of cyber-physical technologies shaping Industry 4.0 and the benefits to suppliers, producers and customers		<b>D2</b> Evaluate the design and implementation of a cyber-physical systems architecture for Industry 4.0 based manufacturing systems
<b>P3</b> Examine the relationship between cyber-physical production systems (CPPS) and the Internet of Things (IoT)  <b>P4</b> Review a range of wireless communication protocols available for the smart factory	<b>M2</b> Analyse the principles and benefits of cloud computing and its role with suppliers, manufacturers and customers within Industry 4.0  <b>M3</b> Investigate the challenges and solutions regarding data analytics in smart factories	

Pass	Merit	Distinction
<b>L03</b> Examine the factors manufacturers need to consider when transitioning from Industry 3.0 to 4.0		<b>D3</b> Evaluate the organisational impact and change management methods used when transitioning from Industry 3.0 to 4.0
<p><b>P5</b> Examine the considerations and challenges manufacturers need to consider when implementing data collection and data management for a smart factory</p> <p><b>P6</b> Explore the transition from Industry 3.0 to 4.0, within a manufacturing sector</p>	<b>M4</b> Explore the functional safety considerations when transitioning to a fully automated smart factory	
<b>L04</b> Explore futuristic trends in manufacturing and the factors shaping Industry 5.0.		<b>D4</b> Evaluate the future of manufacturing in Industry 5.0 and beyond
<b>P7</b> Explore the key factors and stakeholders that are causing a transition from Industry 4.0 to 5.0	<b>M5</b> 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](http://www.infineon.com)

Infineon

Discoveries, Cloud Computing, Safety and Security with Robots, Industry 4.0, Big Data (General Reference)

[www.analog.com](http://www.analog.com)

Analog Devices

Functional Safety and Industry 4.0 (Article)

[www.eurogeography.eu](http://www.eurogeography.eu)

Eurogeo

Depots (General Reference)

[www.supplychaingamechanger.com](http://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 76: Introduction to Professional Engineering Management

**Unit code** R/617/3938

**Unit level** 4

**Credit value** 15

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

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

## 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](http://www.engc.org.uk)

Engineering Council

UK-SPEC – UK Standard for Professional Engineering Competence  
(General Reference)

[www.ewb-uk.org](http://www.ewb-uk.org)

Engineering without Borders  
Becoming a Professional Engineer  
(General Reference)

### Links

This unit links to the following related units:

*Unit 4: Managing a Professional Engineering Project*

*Unit 35: Professional Engineering Management*

## Unit 77: Industrial Robots

<b>Unit code</b>	<b>L/617/3940</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### 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

Pass	Merit	Distinction
<b>L01</b> Describe the operational characteristics, selection criteria and applications of industrial robots within manufacturing industries		<b>L01 and L02</b> <b>D1</b> Evaluate the selection of a safety-compliant industrial robot system for a given manufacturing application
<b>P1</b> Review the types of industrial robots and their applications within manufacturing industries	<b>M1</b> Analyse the features and operation of six axis robots within manufacturing applications	
<b>P2</b> Describe selection criteria for industrial robot applications		
<b>L02</b> Explain the safety standards associated with industrial robots		
<b>P3</b> Outline the principles and methods of functional safety analysis within automated manufacturing	<b>M2</b> Develop hazard and risk assessment for an industrial robot manufacturing system	
<b>P4</b> Explain the safety criteria for robot cells within manufacturing applications		
<b>L03</b> Program an industrial robot for automated process application		<b>D2</b> Design, develop and test a robot program for a series of automated industrial tasks
<b>P5</b> Investigate the range of programming languages and methods available for industrial robots	<b>M3</b> Analyse offline and online programming methods for industrial robots	
<b>P6</b> Program an industrial robot to perform a simple task		
<b>L04</b> Investigate the global economic scope of industrial robots and integration into smart factories.		<b>D3</b> Evaluate the global economics of increased robot density in smart factories and the impact on the human workforce
<b>P7</b> Assess the advantages and scope of collaborative robots over traditional methods	<b>M4</b> Analyse the benefits of artificial intelligence within industrial robotics and contribution to Industry 4.0	
<b>P8</b> Investigate advances in industrial robot technology		

## 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](http://www.machinedesign.com)

Machine Design

The difference between, Cartesian, six-axis and SCARA robots  
(General Reference)

[www.nipponpulse.com](http://www.nipponpulse.com)

Nippon Pulse America

Basics of servomotor control  
(General Reference)

[www.iso.org](http://www.iso.org)

International Organization for Standardization  
Robots and robotic devices – safety requirements for industrial robots  
(General Reference)

[www.robotics.org](http://www.robotics.org)

Robotics Online

Robotic resources, emerging markets, safety and standards  
(General Reference)

[www.ifr.org](http://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 15: Automation, Robotics and Programmable Logic Controllers (PLCs)*

*Unit 16: Instrumentation and Control Systems*

*Unit 42: Further Programmable Logic Controllers (PLCs)*

*Unit 54: Further Control Systems Engineering*

*Unit 75: Industry 4.0*

*Unit 78: Programmable Logic Controllers (PLCs)*

# Unit 78: Programmable Logic Controllers

**Unit code** Y/617/3942

**Unit level** 4

**Credit value** 15

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## 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
<b>L01</b> Describe the design, operation and selection of PLC systems		<b>D1</b> Justify the selection of a programmable logic controller for a given application
<p><b>P1</b> Describe the architecture and operation of programmable logic controllers</p> <p><b>P2</b> Compare the design and applications of Compact, modular and rack-mounted PLCs</p> <p><b>P3</b> Describe the range of input/output devices and PLC interface techniques</p>	<p><b>M1</b> Analyse the suitability of programmable logic controllers (PLCs) with programmable automation controllers (PACs) for given applications</p>	
<b>L02</b> Explore Functional Safety within PLC systems		<b>D2</b> Evaluate functional safety and the integration of functional safety within PLC systems to minimise hazards and risks
<p><b>P3</b> Explore the requirement of functional safety within industrial PLC systems</p> <p><b>P4</b> Compare the range of IEC6113-3 languages and their applications</p>	<p><b>M2</b> Apply functional safety analysis on a PLC based automated process system.</p>	
<b>L03</b> Develop a PLC program for an automated process system		<b>D3</b> Evaluate the PLC program for an automated process system and make justifiable modifications
<p><b>P5</b> Translate a digital logic control circuit into an equivalent PLC program</p> <p><b>P6</b> Produce design and planning documentation associated with the preparation of a PLC program</p> <p><b>P7</b> Design and develop a functionally safe PLC program for an automated process system</p>	<p><b>M3</b> Apply methods of testing and debugging hardware and software in PLC systems</p>	



Pass	Merit	Distinction
<p><b>LO4</b> Review how PLCs exchange information and process signals with other devices.</p>		<p><b>D4</b> Evaluate Fieldbus and Ethernet Technologies for industrial manufacturing applications</p>
<p><b>P8</b> Describe the characteristics and methods of digital data communication for PLCs</p> <p><b>P9</b> Review common communication technologies available on a range of PLCs</p>	<p><b>M4</b> Assess the use and integration of SCADA and HMI's with PLCs in industry</p>	

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

*Unit 16: Instrumentation and Control Systems*

*Unit 42: Further Programmable Logic Controllers (PLCs)*

*Unit 54: Further Control Systems Engineering*

*Unit 75: Industry 4.0*

*Unit 77: Industrial Robots*

# Unit 79: Computer Aided Design (CAD) for Engineering

<b>Unit code</b>	<b>M/617/6409</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Computer Aided Design (CAD) is the use of computer technology in engineering industries, enabling the exploration of design ideas, the visualising of concepts and to simulate how a design will look and perform in the real world prior to production. The ability to analyse, modify and optimise a Computer Generated Image (CGI), object and/or 3D environment is an integral part of the design process in all areas of engineering.

This unit aims to provide students with opportunities to develop their understanding and knowledge of CAD software applications used in engineering, and the practical skills to utilise the technology within their own creative work.

On successful completion of this unit students will be able to understand the current and prospective uses of CAD technology within engineering, and be able to produce CAD drawing, objects, 3D environments and visualisations.

## Learning Outcomes

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

1. Discuss the role of CAD in different engineering contexts and its influence on design and manufacturing processes in areas of specialist practice.
2. Use 2D and 3D CAD software to produce visualisations and technical drawings.
3. Present drawings and renderings, for a given project, produced using CAD software.
4. Evaluate the way in which CAD software may integrate into production processes.

## Essential Content

**LO1 Discuss the role of CAD in different engineering contexts and its influence on design and manufacturing processes in areas of specialist practice.**

*CAD hardware*

*CAD software applications*

*Products produced using CAD*

*Computer data storage of CAD files*

*CAD as used in Product design*

*Computer Aided Manufacturing (CAM)*

*Computer Aided Engineering (CAE)*

*3D printing technology*

*Sustainability*

**LO2 Use 2D and 3D CAD software to produce visualisations and technical drawings.**

*Conventions*

Orthogonal Drawings

Isometric/Axonometric Drawings

Technical Drawings

Scale

Line thickness/line types

Annotation

*3D Modelling Conventions*

Solid modelling

Surface modelling

Materials/surface finishes

Lighting

**LO3 Present drawings and renderings, for a given project, produced using CAD software.**

*Drawing formatting*

Drawing sizes/sheet sizes

Visual representation

Accurate scaling

Title blocks

*Output formats*

File types

Printing methods

Rendering methods

Wireframe

Hidden line

Shaded

Photorealistic

**LO4 Evaluate the way in which CAD software may integrate into production processes.**

*Digital and non-digital workflows*

Integrating with other software

*Digital Production*

*Digital Prototyping*

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<p><b>LO1</b> Discuss the role of CAD in different engineering contexts and its influence on design and manufacturing processes in areas of specialist practice.</p>		<p><b>D1</b> Assess recent developments in CAD/CAM techniques and practices and their use in industry.</p>
<p><b>P1</b> Analyse the use of Computer Aided Design (CAD) in different Engineering contexts.</p> <p><b>P2</b> Compare traditional and CAD-enabled processes in Engineering.</p>	<p><b>M1</b> Evaluate how the use of CAD may be beneficial, or problematic, in different Engineering contexts.</p>	
<p><b>LO2</b> Use 2D and 3D CAD software to produce visualisations and technical drawings.</p>		<p><b>D2</b> Produce finished 2D and 3D CAD outputs; which are accurately scaled, providing key technical information and communicate dimensions, materials and surface finishes.</p>
<p><b>P3</b> Produce 2D drawings, exploring the technical and physical parameters of an Engineering project.</p> <p><b>P4</b> Develop 3D models and visualisations to experiment with form, material and surface finish.</p>	<p><b>M2</b> Use 2D and 3D CAD drawings and visualisations as part of an iterative Engineering development process.</p>	

Pass	Merit	Distinction
<b>L03</b> Present drawings and renderings, for a given project, produced using CAD software.		<b>L03 L04</b>
<p><b>P5</b> Prepare a set of CAD drawings for a given project.</p> <p><b>P6</b> Evaluate the ability of CAD to enhance a project workflow.</p>	<b>M3</b> Use industry standard conventions in the production and presentation of 2D and 3D CAD output.	<b>D3</b> Present finished 2D and 3D CAD outputs; integrating the use of related software and traditional production techniques to develop outputs that communicate the technical and aesthetic properties of an Engineering project.
<b>L04</b> Evaluate the way in which CAD software may integrate into production processes.		
<p><b>P7</b> Evaluate the integration of CAD/CAM into own design and development process.</p> <p><b>P8</b> Discuss how CAD may impact upon the design process.</p>	<b>M4</b> Compare traditional and CAD enabled production in relation to efficiency and accuracy.	

## Recommended Resources

### Textbooks

OMURA, G. and BENTON, B.C. (2018) *Mastering AutoCAD 2019 and AutoCAD LT 2019*. Sybex.

LIPSON, H. and KURMAN, M. (2013) *Fabricated: The new world of 3D printing*. John Wiley.

Shumaker, T.M., Madsen D.A. and Madsen D.P. (2019) *AutoCAD and Its Applications Basics 2019*. Goodheart-Willcox.

### Links

This unit links to the following related units:

*Unit 1: Engineering Design*

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

*Unit 32: CAD for Maintenance Engineers*

*Unit 37: Virtual Engineering*

*Unit 40: Commercial Programming Software*



## Unit 80:

## Welding Technology

<b>Unit code</b>	<b>D/617/7586</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

### Introduction

Many of the things we take for granted, such as motor vehicles, buildings and bridges, rely on welded joints to hold them together. The in-service performance of a welded joint depends on many factors including; the selected welding process, the materials being joined, the skill of the operator and the subsequent service conditions of the welded joint and the host component.

This unit introduces students to a range of manual and automated welding processes, equipment and applications that form part of the manufacturing process of joining by welding. The importance of the underpinning metallurgical properties of the weld materials, the effect of heat and weld induced stress and the importance of correct weld design and implementation will also be covered.

On the successful completion of this unit the student will be able to describe common welding processes and demonstrate how the metallurgical properties of the weld materials, the correct weld design and implementation affect the performance of the weld during and post, welding operations.

**Note:** Welding and Welding Inspection are primarily practical tasks, this unit, together with Unit 81: Welding Inspection have been designed to support practical training in welding and welding inspection with the appropriate and necessary theory. It is anticipated that a student studying this unit will have prior experience of welding at Level 3.

## **Learning Outcomes**

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

- 1 Describe the fundamental principles of welding processes and equipment.
- 2 Demonstrate how the metallurgical properties of weld materials effect the performance of welded joints.
- 3 Show how weld construction and design can influence the behaviour of welded structures under different types of loading.
- 4 Demonstrate how weld stresses can affect a weld construction, their causes, avoidance and control measures.

## Essential Content

### LO1 Describe the fundamental principles of welding processes and equipment

#### *Oxy-gas welding and related processes:*

Fundamentals of oxy-gas combustion

Characteristics of different fuel gases

#### *Fundamentals of an electric arc:*

Characteristics; limitations and applications

Power sources for arc welding, difference performance of AC/DC sources, importance of polarity

Shielded arc welding; purpose of gas shield, types of gas used, control of shield gas and post weld operations. Effect of shielding gas on the post-weld properties of the weld joint

#### *Fundamentals; equipment, applications and procedures for welding processes:*

Tungsten-inert gas (TIG) welding

Metal Inert Gas (MIG) / Metal Active Gas (MAG) and Flux Cored welding

Manual Metal arc welding

Submerged-arc welding

Resistance welding

#### *Other welding and associated processes:*

Plasma, electron beam, Laser, electro-slag, friction, magnetic pulse welding, ultrasonic, high-frequency, stud and others

Cutting and other edge preparation processes

Automated / fully mechanised processes and robotics

**LO2 Demonstrate how the metallurgical properties of weld materials effect the performance of welded joints**

*Requirements for testing materials and welded joints:*

Quality control, regulations governing welded structures, UK, European and International. Methods of examination of welding joints, applications and differences between macro and micro-structural composition and examination

*Structure of the welded joint:*

Formation and properties of the different metallurgical structures within a weld, variation with process, temperature and material. Definition and importance of the Heat Affected Zone (HAZ). Need for multi-pass joints and possible problems compared to single pass welded joints

*Metallurgical effects induced by welding in:*

Carbon and Carbon-Manganese steels.

High-alloyed (stainless) steels

Cast irons and cast steels

Nickel and Nickel alloys

Aluminium and aluminium alloys

*Cracking mechanisms in welded joints:*

Short and long-term effects, causes and avoidance measures, monitoring to prevent poor welds

*Principles of joining dissimilar materials:*

Requirement for welding dissimilar materials, precautions and safeguards, processes and testing

**LO3 Show how weld construction and design can influence the behaviour of welded structures under different types of loading**

*Influences affecting welded joint design:*

Material being welded, plate or sheet thickness, wall thickness of welded pipes, accessibility, loading, welding process, rate of heat input and total heat input, welding position

*Relationship between external loads on structures, internal forces and the stresses induced by welds:*

Strength of welded joint and weld area, loads across discontinuous surfaces, surface finish. Effect of in-service, post-weld, operational temperatures and pressures (internal and external)

*Behaviour of welded structures under dynamic and static loading:*

Design of welded pressure equipment for different applications (corrosive content, medical, aerospace and nuclear). Design of aluminium alloy structures under varying loads and in differing environments. Use of protective coatings.

#### **LO4 Demonstrate how weld stresses can affect a weld construction, their causes, avoidance and control measures**

*Contraction and distortion due to weld induced stress in joints and structures:*

Control Measure and procedures to minimise distortion and stress, effects of induced stresses on the behaviour of a structure in service. Causes and relief of post-weld residual stresses. Consideration of all process variables, previously described on LO2 on weld induced stress, including: Formation and properties of the different metallurgical structures within a weld, variation with process, temperature and material. Importance of the Heat Affected Zone (HAZ). Problems caused by use of multi-pass joints

*Plant facilities, welding jigs and fixtures:*

Workshop layout for improved productivity, safety and comfort

Advantages of using fixtures, jigs and positioners, auxiliary equipment, fume extraction, heat treatment and temperature control equipment

Facilities for handling and storing welding consumables

*Health and safety hazards associated with welding and fabrication processes:*

Risk factors associated with welding from electricity, gases, fumes, fire, radiation and noise

*Health and safety regulations:*

National, European and international regulations and codes of practice. Safe working procedures to ensure the requirements are met, operator skills updating and testing.

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Describe the fundamental principles of the welding processes and equipment		<b>D1</b> Evaluate the most appropriate welding process for a given application and material type
<p><b>P1</b> Describe the fundamental characteristics of the electric arc and oxy-gas welding</p> <p><b>P2</b> Explain how the selection of current (AC/DC) and polarity can affect the structure of the weld</p>	<b>M1</b> Explain how the choice of shielding gas can affect the properties of a weld	
<b>LO2</b> Explain how the metallurgical properties of weld materials effect the performance of welded joints		<b>D2</b> Discuss the fundamentals of cracking mechanisms in welded joints and the way in which welding variables affect the incidence of cracking
<p><b>P3</b> Illustrate how the areas of the Heat Affected Zone (HAZ), and their influence on the material properties of the weld</p> <p><b>P4</b> Describe the process of the specimen preparation for micro and macro examination</p>	<b>M2</b> Explain how multi-pass welds can significantly reduce stress in the weld microstructure	
<b>LO3</b> Show how weld construction and design can influence the behaviour of welded structures under different types of loading		<b>D3</b> Analyse the importance of welding joint design and how it can be influenced by material type, material thickness, accessibility, loading, welding process and welding position
<b>P5</b> Show how weld construction and design can influence the behaviour of welded structures under different types of loading	<b>M3</b> Explain the effect that high pressure and temperature can have on a weld construction over time	

Pass	Merit	Distinction
<b>LO4</b> Explore how weld stresses can affect a weld construction, their causes, avoidance and control measures		<b>D4</b> Assess how the relevant health and safety regulations, with respect to the welding process, are most effectively applied
<p><b>P6</b> Explore how welding sequence and techniques can help to reduce residual stresses or distortion</p> <p><b>P7</b> Investigate the advantages of using fixtures, jigs and positioners</p>	<b>M4</b> Demonstrate how residual stresses may affect the behaviour of a structure in service	

## Recommended Resources

### Textbooks

TIMINGS, R (2011) *Fabrication and Welding Engineering*. Oxen: Routledge

### Websites

[www.theweldinginstitute.com](http://www.theweldinginstitute.com)

The Welding Institute is the leading international membership body for welding and joining professionals. (general reference)

[www.iiwelding.org](http://www.iiwelding.org)

International Institute of Welding operates as the global body for the science and application of joining technology, providing a forum for networking and knowledge exchange among scientists, researchers and industry. (general reference)

### Links

This unit links to the following related units:

*Unit 3: Engineering Science*

*Unit 7: Machining and Processing of Engineering Materials*

*Unit 9: Materials, Properties and Testing*

*Unit 14: Production Engineering for Manufacture*

*Unit 77: Industrial Robots*

*Unit 81: Welding Inspection*



## Unit 81:

# Welding Inspection

<b>Unit code</b>	<b>H/617/7587</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

### Introduction

Welding is a widely used, safe and reliable method of joining materials. The strength and integrity of the welded joint is fundamental to its in-service performance. This performance is assured by vigorous inspection processes which form part of a comprehensive quality control programme.

This unit introduces students to the role of inspection in weld construction, the purpose and value of welding procedure and welder performance testing, as well as the range of non-destructive testing methods that can be employed to identify weld imperfections that could lead to in-service failure. The role and operation of quality assurance systems is also covered

On the successful completion of this unit the student will be able to describe the purpose of weld process and operator performance testing, demonstrate an understanding of a range of non-destructive methods, their application and limitations. They will appreciate the roll and operation of quality assurance systems and be able to identify the most appropriate testing method with regard to material type, size and potential weld imperfections as well as an understanding of the economic impact resulting from failure of the joints for people, products and the environment.

**Note:** Welding and Welding Inspection are primarily practical tasks, this unit, together with Unit 80: Welding Technology have been designed to support practical training in welding and welding inspection with the appropriate and necessary theory. It is anticipated that a student studying this unit will have prior experience of welding at Level 3.

## **Learning Outcomes**

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

- 1 Describe the role and importance of inspection in weld construction
- 2 Illustrate the purpose and value of welding procedure and welder performance testing
- 3 Explain the operation and application of Non-destructive Testing (NDT)
- 4 Demonstrate the role of quality assurance systems in the welding process.

## Essential Content

### LO1 Describe the role and importance of inspection in weld construction

#### *Requirements for testing materials and welded joints:*

Quality control, regulations governing welded structures, UK, European and International. Special application testing, e.g. nuclear

Need for inspection of the weld process and operator inspection

Roles and responsibilities of welding inspectors, relationship with other welding and inspection personnel. Role in maintaining standards of production and post-weld performance

#### *Testing methods:*

Overview of purpose and operation of destructive and non-destructive testing

Types of destructive testing used in weld process and operator inspection

#### *Terminology:*

Terms and definitions used in testing and inspection processes.

### LO2 Illustrate the purpose and value of welding procedure and welder performance testing

#### *Testing requirements:*

Test requirements for procedure and performance testing/standardisation

#### *Weld imperfections:*

Clarify the characteristics of the fundamental types, possible position of weld imperfections and defects, their visibility with the current non-destructive testing (NDT) techniques

Morphology of weld imperfections and their possible influence. National, European and international standards and codes for acceptance/rejections of weld imperfections

#### *Types of destructive testing used in weld process and operator inspection:*

Sectioning of weld joint, preparation for inspection, etching and examination. Macro etch testing, fillet weld break test, transverse tension test and guided bend test

### **LO3 Explain the operation and application of Non-destructive Testing (NDT)**

*Fundamentals, applications and specifications of NDT:*

Operating principles and applications of: Liquid penetrant testing (LPT), magnetic particle testing (MPI), radiographic testing (RT), ultrasonic testing (UT) and Eddy current testing (ECT). Computed tomography (CT) scanning and developed acoustic emission techniques

*Interpretation and economics of testing:*

Interpretation of specific imperfections in welds revealed by above tests.  
Economic considerations of testing operations applied to welded fabrications

### **LO4 Demonstrate the role of quality assurance systems in the welding process**

*Quality assurance:*

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

Quality assurance responsibilities associated with inspection activities as they relate to individuals, company organisation, generation and retention of records

Risks related with a collapse or a failure of the joints for individuals, organisation, products and environment

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Describe the role and importance of inspection in weld construction		<b>D1</b> Evaluate the role of inspection in assuring product quality
<b>P1</b> Describe the role and responsibilities of welding inspectors  <b>P2</b> Explain welding inspection and NDT terms	<b>M1</b> Analyse the purpose and value of testing in relation to service performance	
<b>LO2</b> Illustrate the purpose and value of welding procedure and welder performance testing		<b>D2</b> Evaluate how defects can impact on in-service performance of components and structures
<b>P3</b> Illustrate the different type of commonly encountered weld imperfections  <b>P4</b> Specify the most likely causes of weld imperfections to the different welding processes and welded materials	<b>M2</b> Explain the requirements for materials used for procedure and performance testing / standardisation	
<b>LO3</b> Explain the operation and application of Non-destructive Testing (NDT)		<b>D3</b> Evaluate NDT methods in terms of interpretation and economics of testing operations
<b>P5</b> Identify the types and location of imperfections expected to be found using magnetic particle and dye penetrant testing techniques  <b>P6</b> Describe the principles of ultrasonic, radiographic and Eddy Current testing techniques	<b>M3</b> Explain how accuracy of detection is related to NDT processes, material type and size of construction	

Pass	Merit	Distinction
<p><b>LO4</b> Explore how weld stresses can affect a weld construction, their causes, avoidance and control measures</p>		<p><b>D4</b> Evaluate the risks related with a collapse or a failure of welded joints for individuals, organisation, products and the environment</p>
<p><b>P7</b> Describe the role of the inspector during fabrication activities</p> <p><b>P8</b> Illustrate the importance of keeping accurate records and monitoring of activities with respect to the inspection process</p>	<p><b>M4</b> Analyse the responsibilities associated with inspection activities as they relate to individuals, company organisation, generation and retention of records</p> <p><b>M5</b> Differentiate between the inspection process and the role of a quality assurance process</p>	

## Recommended Resources

### Textbooks

WONG, S.B. (2014) *Non-Destructive Testing – Theory, Practice and Industrial Applications*. Saarbrücken: LAP (Lambert Academic Publishing)

### Websites

[www.theweldinginstitute.com](http://www.theweldinginstitute.com)

The Welding Institute is the leading international membership body for welding and joining professionals.

(general reference)

[www.bindt.org](http://www.bindt.org)

British Institute of Non-Destructive Testing. Covering NDT in its widest sense. Each issue includes technical articles on a broad range of subjects and general news stories affecting the whole industry.

(general reference)

### Links

This unit links to the following related units:

*Unit 3: Engineering Science*

*Unit 7: Machining and Processing of Engineering Materials*

*Unit 9: Materials, Properties and Testing*

*Unit 14: Production Engineering for Manufacture*

*Unit 77: Industrial Robots*

*Unit 80: Welding Technology*

*Unit 82: Statistical Process Control*

## Unit 82:

# Statistical Process Control

<b>Unit code</b>	<b>R/617/3924</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### 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

Pass	Merit	Distinction
<b>LO1</b> Review the quality control function of inspection and measurement		<b>D1</b> Evaluate how the monitoring of process outputs can be used to ensure standards and conformance to a given design specification are maintained
<p><b>P1</b> Review the importance of inspection and measurement in the quality control of a process</p> <p><b>P2</b> Distinguish the significance between natural and assignable causes of variation</p>	<p><b>M1</b> Analyse data to construct the frequency distribution and calculate the mean, range and standard deviation of a given process</p>	
<b>LO2</b> Select data to construct process control charts and determine a control program for a specified application		<b>D2</b> Initiate a control program for a specified application
<p><b>P3</b> Explain how data can be chosen to create process control charts that will enable decisions to be made effectively</p> <p><b>P4</b> Select data to construct process control charts and present</p>	<p><b>M2</b> Analyse sample data from variable inspection and attributive inspection to determine appropriate control chart limits</p>	
<b>LO3</b> Investigate the process capability of a system to meet the specified quality requirement of a component using modified control chart limits		<b>D3</b> Evaluate the processes of a system against a given quality requirement
<p><b>P5</b> Describe the characteristics that need to be considered when determining the process capability of a given process</p>	<p><b>M3</b> Analyse the purpose of modified control chart limits</p>	

Pass	Merit	Distinction
<b>LO4</b> Report the variation found within the output of a process.		<b>D4</b> Determine an effective response to any deviation from the acceptable quality thresholds
<b>P6</b> Demonstrate effective and accurate methods to record variation in output quality of a range of processes	<b>M4</b> 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

*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 83:

# Telecommunication Principles

<b>Unit code</b>	<b>K/618/1785</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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### Introduction

Telecommunication deals with the transmission of information such as voice, images and data using three elements: transmitter, medium and receiver. Applications of telecommunications are all around us including mobile phones, satellite TV, computer networks, Bluetooth and Wi-Fi.

This unit starts with the fundamental principles of wireless communication systems including frequency spectrum and the sources of noise and interference. Theories and practices of analogue and digital communication are then analysed. The unit further covers the physical practicalities of telecommunication systems such as guided and unguided transmission media, security and network architectures.

It is essential that students have successfully completed level 4 or equivalent units containing electrical circuit theory and analogue / digital electronics before undertaking this unit.

### Learning Outcomes

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

1. Develop fundamental knowledge of analogue electronic communication.
2. Analyse digital communication techniques.
3. Assess transmission channels and applications
4. Investigate the design of Data Networks.

## Essential Content

### LO1 Develop fundamental knowledge of analogue electronic communication

#### *Characteristics and performance:*

Sinusoid relationships: frequency, wavelength and velocity.

RF spectrum: ULF, LF, MF, VHF and EHF, Bandwidth, Gain and Attenuation, use of the decibel (dB) Noise: Sources; Internal, external, natural and man-made.

Effects; Interference, cascaded systems, Calculations; signal to noise ratio, thermal noise, noise factor and power.

#### *Modulation Techniques:*

Amplitude modulation (AM); Applications, carrier frequency, baseband signal, mixers, time and phase representation, modulator and de-modulator circuits, double sideband suppressed carrier (DSB-SC), single sideband suppressed carrier (SSB-SC). Frequency modulation (FM); Applications, Bessel coefficients, Carson's rule, wideband, narrowband, varicap diode circuit, crystal-controlled phase locked loop (PLL), PLL demodulator circuits. Phase Modulation (PM); Phase shift keying; Binary, Quadrature, 8 point and 16 point.

#### *RF Transmitter and Receiver Circuits:*

Transmitters; Oscillators, Modulation, Power Amplifiers, Matching, Antennas.

Receivers; Low Noise Amplifiers, Mixers, Tuning Circuits, Detectors. Filtering;

Bandpass Chebyshev and Butterworth designs. The Super Heterodyne Receiver.

### LO2 Analyse digital communication techniques

#### *Digital Communication Fundamentals:*

Digital Data; Coder-Decoder (CODEC), Baud Rate, Bandwidth, Multiplexing

Analogue to Digital Conversion (ADC); Dynamic range, quantization error, conversion rate, noise. Sampling, Nyquist Theorem, Digital to Analogue

Conversion (DAC); Accuracy, Linearity, Monotonicity, Conversion time, Resolution Shannon's Theory, Design trade-offs meeting objectives against constraints.

### *Digital Modulation:*

Data transmission; Baseband digital signalling, digital receiver/generator, non-return to zero (NRZ) and return to zero (RZ), Spectrum of a pulse, effects of noise, raised cosine filter, limitations of baseband signalling. Pulse Coded Modulation (PCM); Carrier Based Signalling; Amplitude shift keying (ASK), Frequency shift keying (FSK), Phase shift keying (PSK), Binary phase shift keying (BPSK), filtering techniques, Digital Signal Processors (DSP).

Orthogonal frequency division multiplexing; Quadrature amplitude modulation (QAM) and Quadrature phase shift keying (PSK).

Coding and Decoding; Hamming, Cyclic-Redundancy, Convolution, Maximum-likelihood Viterbi, Reed-Solomon

## **LO3 Assess transmission channels and applications**

### *Characteristics and Selection criteria:*

Transmission line theory; reflections, standing waves and return loss

Channel terminology; Propagation delay, attenuation, data transfer rate security, mechanical strength, physical dimensions, throughput. configuration, gauge, bandwidth, error performance, distance, cost, capacity.

### *Media Types:*

Guided; Copper wires, twisted pair, coaxial cable, fibre optics, power line carrier

Unguided; Infrared, radio wave, microwaves, lasers, satellite radio,

### *Applications:*

Telephone, computer data transfer, television, radio frequency transmitters and receivers, digital audio, satellite communication, Ethernet, smart grids, video, Bluetooth, paging, global positioning system (GPS), Wi-Fi, WiMax, Radar, Dedicated Short Range Communication (DSRC) for vehicles, internet of things.

### *Security:*

Implications of unsecured wireless network,

Classifications; spoofing, tampering, repudiation, information disclosure, denial of service, elevation of privilege (STRIDE)

Standards; ISO27002, IEC-62443



## LO4 Investigate the design of Data Networks

### *Network Types:*

Personal Area Network (PAN), Local Area Network (LAN), Metropolitan Area Network (MAN), Wide Area Network (WAN), Internetwork (Internet)

### *Network Topologies:*

Point-to-point, Bus, Star, Ring, Mesh, Tree, Daisy Chain, Hybrid

### *Network Layers:*

Open System Interconnect (OSI) standard layers; Application, Presentation, Session, Transport, Network, Data Link, Physical.

Internet Model; TCP/IP protocol suite

### *Network Security:*

Threats; Interruption, Privacy-Breach, Integrity, Authenticity

Cryptography encryption; Secret Key, Public Key, Message Digest

### *Network Switching:*

Categories; Circuit, Message, Packet. Schemes; Space / time division

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Develop fundamental knowledge of analogue electronic communication systems.		<b>D1</b> Design a theoretical bandpass filter circuit as part of a RF receiver from a given specification.
<p><b>P1</b> Identify the range of radio frequency (RF) bands and their applications.</p> <p><b>P2</b> Examine types of noise, their sources and effects on electronic communication systems.</p> <p><b>P3</b> Discuss the range of applications inductors and capacitors in play in RF transmitters and receivers.</p> <p><b>P4</b> Differentiate modulation techniques by comparing Amplitude (AM), Frequency (FM) and Phase Modulation (PM).</p>	<p><b>M1</b> Illustrate the sections of a complete RF transmitter and receiver system outlining the function of each section.</p> <p><b>M2</b> Evaluate the properties of radio antennas and compare designs for AM and FM communication.</p>	
<b>LO2</b> Analyse digital communication techniques.		<b>D2</b> Evaluate the trade-offs, when meeting design objectives under the constraints and limitations of digital communication.
<p><b>P5</b> Explain the aliasing problem of sampled data and methods to mitigate this.</p> <p><b>P6</b> Analyse the main performance specifications for ADC and DAC in a digital communication system.</p> <p><b>P7</b> Describe the operation of a multiplexed PCM transmitter system.</p> <p><b>P8</b> Compare different techniques to modulate and demodulate digital data.</p>	<p><b>M3</b> Discuss a range of methods to reduce noise and improve the quality of signals in digital communication systems.</p> <p><b>M4</b> Analyse coding methods for transmission reliability in digital communication.</p>	

Pass	Merit	Distinction
<b>LO3</b> Assess transmission channels and applications		<b>D3</b> Select and justify a guided or unguided communication system solution for a given case study.
<p><b>P9</b> Define the general characteristics of transmission channel media.</p> <p><b>P10</b> Assess guided and unguided transmission channel media including applications.</p>	<p><b>M5</b> Investigate security issues of unguided communication systems and methods of mitigating the risks.</p>	
<b>LO4</b> Investigate the design of Data Networks.		<b>D4</b> Present a design proposal for a data network from a given specification.
<p><b>P11</b> Describe the geographical categories of data networks.</p> <p><b>P12</b> Illustrate the differences between popular data network topologies.</p> <p><b>P13</b> Explain with examples the principles of layered architecture for data networking.</p> <p><b>P14</b> Investigate switching techniques in data networks.</p>	<p><b>M6</b> Investigate methods to control traffic congestion on data networks.</p>	

## Recommended Resources

### Textbooks

DODD, A.Z. (2018) *The essential guide to Telecommunication*, Prentice Hall.

HOROWITZ, P. and HILL, W. (2015) *The Art of Electronics*.

SIBLEY, M. (2018) *Modern Telecommunications Basic Principles and Practices*, CRC Press.

YOUNG, P.H. (1998) *Electronic Communication Techniques*, Macmillan Publishing.

### Website Tutorials

Store.tutorialspoint.com (2020) Premium Ebooks – Tutorialspoint [online]

Available at: <https://store.tutorialspoint.com/>

### Links

This unit links to the following related units:

*Unit 19: Electrical and Electronic Principles*

*Unit 47: Analogue Electronic Systems*

# Unit 84: Semiconductor Manufacture

<b>Unit code</b>	<b>L/618/1763</b>
<b>Unit level</b>	<b>4</b>
<b>Credit value</b>	<b>15</b>

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## Introduction

Semiconductor device fabrication is a complex production process, involving varying technologies, concepts and specialist equipment and techniques. Each activity can be prone to defects, causing costs to rise and failure to meet customers specifications and reliability. The manufacture of semiconductor wafers and module packages is highly automated to ensure standards are met and yield is maximised.

This unit investigates the equipment and processes used in automated semiconductor device production and module assembly. The physical dimensions of the materials that are being processed are exceedingly small (<10nm) and so to prevent risk of contamination and defects the automatic production environment is hermetically sealed. The external working area is supplied with filtered air. In manufacturing semiconductor devices, it is important to be confident that the device will meet specifications, testing and data collection is both manual and automated, and the information used to confirm process quality and meet wafer yield predictions; any defects are identified and corrective actions taken.

The equipment and techniques used are specialised and it is important to become familiar with the technical language and concepts used to fully develop your skills.

On successful completion of this unit, students will be able to work effectively within the increasingly complex semiconductor manufacturing systems in the semiconductor industry.

## Learning Outcomes

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

1. Describe the operational characteristics, selection criteria and application of equipment used in automated systems for fabricating semiconductor devices
2. Explain the individual process stages in producing a semiconductor wafer suitable for further processing in an automated semiconductor fabrication plant.
3. Discuss the processes necessary to take a semiconductor wafer and produce a finished integrated circuit in an automated semiconductor fabrication plant.
4. Demonstrate how the data collected during the semiconductor manufacturing process from inspection and testing is used to improve the yield of each integrated circuit to final packaging.

## Essential Content

### LO1 Describe the operational characteristics, selection criteria and application of equipment used in automated systems for fabricating semiconductor devices

#### *Semiconductor device fabrication:*

Overview of the entire semiconductor device fabrication manufacturing process

Introduction to terminology, e.g. wafers, deposition, removal, growth, patterning, modification, insulation, interconnectivity.

Underlying principles of how the first semiconductors (Germanium (Ge) and Silicon (Si) material and Negative-Positive-Negative (NPN) and Positive-Negative-Positive (PNP) transistors) were produced. Characteristics of Bipolar junction devices.

A systems approach to integration of semiconductor devices.

Principles of Metal-Oxide-Semiconductor (MOS) technology, Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET).

#### *Operational characteristics and selection of automated equipment for semiconductor fabrication:*

System characteristics of generic semiconductor automated fabrication equipment, e.g., modular, unitary and rack mounted systems,

electrical/mechanical/power characteristics, electronic parameters-speed, scan time, memory, Human Machine Interface, Input/output requirements, communication standards.

### LO2 Explain the individual process stages in producing a semiconductor wafer suitable for further processing in an automated semiconductor fabrication plant

#### *Producing a Pure Silicon wafer:*

The need for a clean environment

Producing a silicon ingot, Czochralski or Floating Zone process

Semiconductor purity

Preventing contamination

*Cutting the individual wafers:*

Surface treatments, solvents, polished to obtain a very regular and flat surface

Thermal Oxidation

Testing of wafer-conductivity

Automatic handling and storage.

Equipment needed to produce a semiconductor wafer, e.g., furnaces for oxidation and gas application, cutting tools to slice the silicon ingot into wafers, cleaning and surface treatment equipment, testing equipment for wafer flatness, surface conductivity, wafer automatic handling equipment.

**LO3 Discuss the processes necessary to take a semiconductor wafer and produce a finished integrated circuit in an automated semiconductor fabrication plant**

*Wafer fabrication (Front-End):*

Multi-step wafer fabrication process. i.e. photo-masking; etching; diffusion; ionic implantation; metal deposition; passivation and back-lap.

Wafer-probing, i.e. process parametric test, full wafer probing test, bad die marked for removal after wafer is cut.

Equipment needed to perform front-end wafer fabrication, e.g., diffusion furnaces, pumps to control flow of gasses, Ion implantation and vacuum equipment, Physical Vapour Deposition system, evaporation and sputtering chambers, Chemical Vapour Deposition equipment, photolithography equipment – resist coating – soft bake ovens – exposure equipment – development of resist to remove or retain mask pattern, wet and dry etching (Chemical or Plasma), waste removal equipment, automatic testing and sorting equipment, automatic handling equipment.

*Wafer packaging and module assembly (Back-End):*

Assembly, i.e. die cutting; inspection and sorting; die attachment to a frame or substrate; wire bonding (or alternative); further inspection and sorting; package encapsulation; leads cutting (if necessary); lead tinning (if necessary); marking; surface mount technology (SMT) and final test.

Equipment needed to perform back end wafer fabrication, e.g. assembly process equipment includes – die cutting equipment and die attachment/bonding machines- automatic handling/ holding- pick and place machines, wire bonding equipment and tools – die placement equipment, glass passivation equipment, moulding process equipment, high precision dispensers, deflash, trim, form and singulation machine (DTFS), solder paste printers, SMT component placer, flux wash system, laser marking and final automatic quality test equipment.



**LO4 Demonstrate how the data collected during the semiconductor manufacturing process from inspection and testing is used to improve the yield of each integrated circuit to final packaging.**

*Data collection:*

Automated data collection during manufacturing process.

Automatic visual tests to identify defects caused by process activity.

Critical Dimension Scanning Electron Microscope (CDSEM)

Go-No/Go Tests.

Parametric test- dynamic checks.

Batch production testing issues.

*Yield analysis:*

Types of faults/defects recorded and analysed to improve future performance.

Failure Mode and Effects Analysis (FMEA).

Process Failure Mode and Effects Analysis (PFMEA). Equipment needed to perform data collection and yield analysis, e.g. automatic test equipment, visual automatic inspection system, data acquisition equipment, software programmes to analyse the data and inform operators in real time. Yield management processes and control plans

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Describe the operational characteristics, selection criteria and application of equipment used in automated systems for fabricating semiconductor devices		<b>D1</b> Analyse the system characteristics of an semiconductor fabrication facility.
<b>P1</b> Describe the operational characteristics of the system for fabricating semiconductor devices on a wafer. <b>P2</b> Explain the difference in semiconductor structure between how a Bipolar junction transistor and MOSFET are made.	<b>M1</b> Explore the selection criteria and application of equipment used in semiconductor fabrication.	
<b>LO2</b> Explain the individual process stages in producing a semiconductor wafer suitable for further processing in an automated semiconductor fabrication plant.		<b>D2</b> Evaluate the methods used on a silicon wafer to prepare it for wafer fabrication.
<b>P3</b> Describe different methods of producing a silicon ingot.	<b>M2</b> Discuss the need for controlling the environment around the production of semiconductor wafers.	
<b>LO3</b> Discuss the processes necessary to take a semiconductor wafer and produce a finished integrated circuit in an automated semiconductor fabrication plant.		<b>D3</b> Evaluate the methods of wafer testing used during the manufacturing process.
<b>P4</b> Explain the various stages of Front-End and Back-End wafer fabrication.	<b>M3</b> Explore the methods used to connect the semiconductor chip to the printed wiring board.	
<b>LO4</b> Demonstrate how the data collected during the semiconductor manufacturing process from inspection and testing is used to improve the yield of each integrated circuit to final packaging.		<b>D4</b> Analyse how data from the manufacturing process is used to improve overall yield.
<b>P5</b> Describe how data is collected during the semiconductor manufacturing process <b>P6</b> Investigate inspection and testing techniques used to improve semiconductor manufacturing processes	<b>M4</b> Identify the principle types of faults and defects likely to occur in a semiconductor manufacturing processes.	

## Recommended Resources

### Textbooks

GENG, H. (2017) *Semiconductor Manufacturing Handbook*, Second Edition. McGraw Hill Professional.

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

MAY, G. and SPANOS, C. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. John Wiley & Sons, Inc.

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

### Journals

*IEEE Transactions on Semiconductor Manufacturing*

*IET Digital Library*

### Links

This unit links to the following related units:

*Unit 20: Digital Principles*

*Unit 22: Electronic Circuits and Devices*

*Unit 52: Further Electrical, Electronic and Digital Principles*

# Unit 85: Semiconductor Production Environments

**Unit code** R/618/1764

**Unit level** 4

**Credit value** 15

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## Introduction

As designers and engineers develop ever more sophisticated electronic equipment, the drive to package increasing amounts of processing power into smaller spaces is relentless. The size of semiconductor devices is measured in nanometres; one nanometre is one billionth of a metre in length and microchips of 10 nanometres are commonplace. Manufacturing devices of this size and complexity is a very specialist process and this unit addresses some of the important issues fundamental to safe and successful manufacture of semiconductors.

The production and assembly of semiconductor devices takes place in factory spaces that are closer in appearance and function to hospital operating theatres than conventional factories. A tiny speck of dust or grease can wreck production, this coupled with the toxic nature of some semiconductor manufacturing materials and processes, calls for particular attention to health, safety and working practices.

This unit will introduce the concept of cleanrooms, explore their design, internal layout and specialist equipment and furniture. The need to control air flow rates and levels of purity in cleanrooms will also be covered as will the need for, and proper use of, personal protective equipment (PPE). The certification, maintenance and cleaning of these facilities together with all aspects of the relevant Health & Safety legislation, good working practices and the concept of Good Manufacturing Practice (GMP) will be introduced. The nature of the toxicity present in semiconductor materials and manufacturing processes will be evaluated. Finally, the assessment and minimisation of risk will be considered.

On successful completion of this unit the student will be familiar with the nature of semiconductor manufacturing operations and be competent to work within such an environment, safely and in a knowledgeable manner, able to identify, assess and minimise risks to processes and people.

## **Learning Outcomes**

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

1. Recognise the role and applicability of Health and Safety legislation and other guidelines in semiconductor manufacturing
2. Describe the different cleanroom arrangements and their relevance to semiconductor manufacturing
3. Investigate the toxicity of the materials and processes employed in semiconductor manufacturing
4. Examine workplace activities in a semiconductor manufacturing environment for assessment, minimisation and management of risk

## Essential Content

### LO1 Recognise the role and applicability of Health and Safety legislation and other guidelines in semiconductor manufacturing

#### *Health and Safety, core considerations:*

The nature of risk and the costs of unsafe working. Recognising responsibility for safe working at individual, corporate and state levels and the consequences of non-compliance. General and specific risk, cultural and social responses to risk. Concept of personal responsibility for the Health and Safety of self and others in the workplace. Role of employee within company management of Health and Safety. Company structures for the management, training and updating of Health and Safety requirements and regulations, actions after Health and Safety breaches or incidents. End of life risks for manufactured products and process discharge.

#### *Health, Safety and Environmental Procedures and Standards:*

Mandatory compliance with UK, European and international health and safety regulations as they apply to the semiconductor manufacturing working environment, working practices and the provision and use of personal protection equipment (PPE).

e.g. Health and Safety at Work Act 1974, Management of Health and Safety Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER) 1998, Control of Substances Hazardous to Health (COSHH) 2002, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Personal Protective Equipment at Work Regulations 1992, Electricity at Work Regulations 1989, Health and Safety (First Aid) Regulations 1981, Control of Pollution (Amendment) Act 1989, BPD/R: Biocidal Products Directive/Regulations (BPD/R), CDG: Carriage of Dangerous Goods, CHIP: Chemicals (Hazard Information and Packaging for Supply), CLP: Classification, Labelling and Packaging of Substances and Mixtures (CLP Regulation), adopting in the EU the Globally Harmonised System (GHS).

The role and powers of the Health and Safety Executive in the UK.

*Company and process specific Health and Safety Requirements and Systems:*

Company safety rules and systems, accident books, provision and maintenance of safety policies, codes of practice and safety audits. Incident reporting and review. Ongoing training of staff, systems for reviewing and managing health and safety, safety circles, safety share, safety committee systems.

Process specific issues; suppliers' guidance for the handling of raw materials, awareness of atmospheric, temperature and process parameters for safe working.

Semiconductor Process; infrastructure in the clean room, e.g. life safety systems for gas and chemical detection, oxygen depletion within the fabrication infrastructure, multiple safety interlocks and fail safe devices on tooling.

**LO2 Describe the different cleanroom arrangements and their relevance to semiconductor manufacturing**

*Semiconductor manufacturing environment:*

Effects of the presence of the smallest particles of dust, grease or production debris on the manufacturing process. Detrimental effect on production operative's health of the liquid or gaseous discharge from the manufacturing process, need to carry away and efficiently filter such discharge. Requirement to create controlled and safe working environments.

*Cleanrooms:*

Rational; the cleanroom as a space in which the level of particulate contamination is controlled within set limits. Requirement to control temperature, humidity, air flow patterns and pressure to minimise the introduction, generation and retention of particles within the cleanroom. Classification of cleanrooms by permitted density of particle size per m<sup>2</sup>, (1-5.µm particles per m<sup>3</sup>), effect and scope of the International Organisation for Standardisation (ISO) classification ISO 14644-1:2015(en) to ISO 14644-9:2012 Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle connection.

Construction of cleanroom; requirement for airtight construction (to allow use of positive pressure within the cleanroom) with easy to clean internal surfaces. Bay, Chase and Ballroom configuration of cleanrooms. Requirements of furniture and fittings used in cleanrooms. Importance of Electrostatic Discharge (ESD) in a cleanroom.

Atmospheric management; requirement for high air exchange rates, rapid air velocities and directed airflows to minimise particle concentration. Positive pressurisation levels, around 10 to 25 Pa, higher than adjacent areas, more air in than out process. Negative pressure exceptions in areas working with specific (hazardous) materials. Air filtration efficiency requirements, use of High Efficiency Particulate Air (HEPA) diffusion filters to remove 99.97% of contaminants of 0.3 microns and above. Leak testing, recovery rates, comfort and pressurisation levels. Use of gas detection systems, oxygen monitors and oxygen analysers where inert gases are used. Requirements for comprehensive fire safety systems.

Testing and certification requirements; relevant national European Union (EU) and international standards. **International Organization for Standardization** (ISO), ISO 14644-1:2015(en) to ISO 14644-9:2012 Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle connection, EU Good Manufacturing Practice (GMP) classification, ISO 14698-1:2003 Cleanrooms and associated environment – Bio-contamination controls – Part 1: General principles and methods, **American National Standards Institute** (ANSI).

Airborne particle concentration testing, airflow readings and Clean Testing and Certification Board (CTCB), CTCB-1 testing, certification and validation. Importance of working within Good Manufacturing Practice (GMP) requirements for semiconductor manufacture.

### LO3 Investigate the toxicity of the materials and processes employed in semiconductor manufacturing

*Sources of toxicity:*

Potential airborne emissions from the manufacturing process including; toxic, reactive and hazardous gases, organic solvents and particulates. Chemicals and gases present include; arsenic, arsine, cadmium, gallium arsenide; hydrochloric, hydrofluoric, phosphoric, nitric and acetic acids; acetone, isopropanol, N-butyl acetate, trichloroethylene, and xylene solvent vapours; Thin film metals including, copper, nickel, iron, chromium, tin, palladium, gold and lead as solder. Also reference precursor materials for Low-k and High-k dielectrics, CMP slurries, ancillary chemicals, wet processing chemicals, photoresists, atmospheric and specialty gasses.

Leaks from nitrogen or argon storage tanks. Nitrogen as an oxidation preventative, for both selective soldering and convection reflow soldering. Argon use in the sputtering deposition process.

Presence of above chemicals in liquid and solid waste, possibility and control of environmental pollution.



*Effects of toxicity:*

Risk of carcinogenic outcome to extreme exposure, risk to the unborn child, headache, nose, throat, lung and eye irritation, vomiting, confusion, diarrhoea and irregular heartbeat have been noted as short-term reactions to exposure of toxic agents.

*Legislation specific to working with toxic materials:*

Control of Substances Hazards to Health (COSHH) 2002, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Health and Safety (First Aid) Regulations 1981, Personal Protective Equipment at Work Regulations 1992, Control of Pollution (Amendment) Act 1989.

*Mitigation methods:*

Controlled and filtered atmospheres in manufacturing areas. Regular and effective maintenance of air control systems with appropriate certification.

Correct use of appropriate personal protective equipment (PPE) including; over suits, gowns, coats, hoods, face masks (Yashmaks), caps, helmets, overshoes or boots, safety goggles, visors and gloves. Correct use of appropriate hazard protection equipment including; breathing apparatus, full protective suits and gloves.

Correct fitting and use of PPE, safe removal, laundering or disposal of contaminated PPE. Prompt reporting of illness or workplace distress.

Use of correct cleaning methods for contaminated work areas. Strict adherence to maintenance schedules.

Controlled removal and disposal of contaminated waste and scrap items.

**LO4 Examine workplace activities in a semiconductor manufacturing environment for assessment, minimisation and management of risk**

*Risk Assessment:*

Rationale for risk assessment. Risk assessment template design, identification of areas to be assessed, completion of risk assessments using the five-step approach; principle hazards, who is at risk, evaluate level of risk and adequacy of mitigation, record findings, review assessment. Risk rating; matrix production e.g. low risk, moderate risk, substantial risk, high risk. Frequency and severity of incidence, evaluation of the rate of occurrence e.g. improbable, possible, occasional, frequent, regular, common; evaluation of severity e.g.; definitions of consequence; level of injury sustained, e.g. graded as trivial, minor, major, multiple major, death, multiple death, types of risk assessment, e.g. Hazard and Operability (HAZOP), qualitative and quantitative risk assessment.

*Adherence:*

Ensuring adherence to risk assessment; regular inspections, spot checks, safety groups.

*Accident and incident reporting:*

Need for accident and incident reporting. Design and completion of accident and incident reporting forms. Collection of evidence e.g.; data, fatigue charts, lighting levels, temperature, time of day. Management responsibility and action on accident and incident reporting.

*Action from accident and incident reporting:*

Use of accident and incident reporting to identify trends and high-risk areas/processes, evaluation of evidence to support the likelihood of, or reoccurrence of, a risk; use of statistical data to assist modification of working process and provision of training in response to findings.

*Emergency evacuation:*

The importance of evacuation procedures in semiconductor manufacturing. Requirement for voice evacuation, visual and acoustic evacuation systems. Evacuation procedures developed from risk assessments and safety audits. Health and safety training developed from risk assessment and safety audits.

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>LO1</b> Recognise the role and applicability of Health and Safety legislation and other guidelines in semiconductor manufacturing		<b>D1</b> Assess how employee engagement can work to reduce risk in semiconductor manufacturing.
<b>P1</b> Detail key requirements of the relevant health and safety regulations as they apply to semiconductor manufacturing processes  <b>P2</b> Show how health and safety policies and company specific guidance are used to reduce risk	<b>M1</b> Review the nature of risks to health and safety in semiconductor manufacturing processes engineering	
<b>LO2</b> Describe the different cleanroom arrangements and their relevance to semiconductor manufacturing		<b>D2</b> Evaluate how working within Good Manufacturing Practice (GMP) guidelines can improve the semiconductor manufacturing process
<b>P4</b> Describe the features of semiconductor manufacture that make the use of cleanrooms essential  <b>P5</b> Identify the environmental parameters that must be managed to ensure safe and effective semiconductor manufacturing in cleanrooms	<b>M2</b> Compare how airborne contaminants are removed from a cleanroom used within the semiconductor manufacturing industry	
<b>LO3</b> Investigate the toxicity of the materials and processes employed in semiconductor manufacturing		<b>D3</b> Analyse the issues around the safe disposal of contaminated waste from semiconductor manufacturing to minimise risks of environmental pollution
<b>P6</b> Identify the primary sources of toxicity present in the semiconductor manufacturing process  <b>P7</b> Describe the type and fit required for personal protection equipment suitable for use in controlled atmosphere situations or processes using inert gas shielding	<b>M3</b> Summarise the relevant Health and Safety legislation as it applies to the use of toxic substances in semiconductor manufacturing	

Pass	Merit	Distinction
<p><b>LO4</b> Examine workplace activities in a semiconductor manufacturing environment for assessment and prevention of risk</p>		<p><b>D4</b> Carry out a full risk assessment on a discrete area of the semiconductor manufacturing process and evaluate its intended effectiveness</p>
<p><b>P8</b> Explain the rationale behind carrying out risk assessments within the semiconductor manufacturing environment</p> <p><b>P9</b> Detail the workplace activities in a semiconductor manufacturing environment to prevent risk</p>	<p><b>M4</b> Develop an emergency action plan and evacuation procedure for a given area of the semiconductor manufacturing process</p>	

## Recommended Resources

### Textbooks

CAMPBELL, S.A. (2001) *The Science and Engineering of Micro-electronic Fabrication*. Oxford University Press.

KALPAKJIAN, S. and SCHMID, S.R. (2014) *Manufacturing Engineering and Technology*. 7th Ed. Pearson

MAY, G.S. and SPANOS, C.J. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. Wiley.

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

### Websites

[hse.gov.uk](http://hse.gov.uk)

Health and Safety Executive

Chemical related legislation

(General reference)

[iso.org](http://iso.org)

International Organisation for  
Standardisation

Cleanrooms and associated controlled  
environments standards

(General reference)

### Links

This unit links to the following related units:

*Unit 20: Digital Principles*

*Unit 22: Electronic Circuits and Devices*

*Unit 52: Further Electrical, Electronic and Digital Principles*

# Unit 86: Emerging Semiconductor Technologies

**Unit code** Y/618/1765

**Unit level** 5

**Credit value** 15

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## Introduction

The digital economy, Big Data and the Internet of Things have been made possible by the developments of semiconductor devices and materials. Without the ability to mass produce complex, reliable, cheap electronic devices our world would look hugely different. This unit looks at the emerging semiconductor technologies that are improving the current methods and processes to increase efficiency, effectiveness and meet new and exciting demands. The semiconductor industry is a dynamic marketplace and to maintain competitive advantage within the field requires each segment to invest in research and development to be able to produce the next generation devices.

There are very few industrial, medical, automotive, and commercial applications that do not use semiconductor devices in some form or other. New requirements and demands are constantly appearing, and this unit will investigate how new techniques and materials in the manufacturing sector can meet these needs as well as identifying the best solutions for customers.

On successful completion of this unit students will be able to adapt latest trends in semiconductor industry in proposing solutions to complex manufacturing problems through improved methods and processes.

## **Learning Outcomes**

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

1. Investigate the properties of emerging semiconductor materials
2. Research new trends and applications for emerging semiconductor technologies
3. Analyse the requirements and equipment used in emerging semiconductor technologies
4. Evaluate the commercial viability of emerging semiconductor technologies

## Essential Content

### LO1 Investigate the properties of emerging semiconductor materials

*Current semiconductor materials and their limitations:*

Materials, e.g. silicon, germanium, gallium arsenide.

Donor and acceptor materials, e.g. boron, antimony, phosphorous, indium, gallium, arsenic, and aluminium.

Physical characteristics, thermal conductivity, e.g. internal noise, electrical limitations (Voltage (V), Current (I), Power (P)), bandwidth, high speed, memory capacity (density) magnetic sensitivity, electrostatic discharge (ESD), and Moore's Law.

*Emerging semiconductor materials and their characteristics:*

Emerging semiconductor materials.

New materials, including enhancements to existing ones, e.g. silicon carbide, gallium manganese arsenide, copper indium gallium selenide, molybdenum disulphide, and bismuth telluride.

Compound semiconductors.

Properties of new materials.

### LO2 Research new trends and applications for emerging semiconductor technologies

*Characteristics of next generation semiconductor devices:*

Research the new materials and assess their suitability and limitations for enhancing current applications, e.g., silicon carbide, compound semiconductors, gallium manganese arsenide, copper indium gallium selenide, molybdenum disulphide bismuth telluride.

Health and safety aspects in using these materials.

Use of new properties of these materials to enhance and improve current performance in existing areas in generic sector areas; e.g., computing, data, automobile, mobile communications, medical.



### LO3 **Analyse the requirements and equipment used in emerging semiconductor technologies**

*Processing technologies needed to handle emerging semiconductor materials:*

Developing trends in the semiconductor processing industry; e.g., technologies used to process silicon carbide with silicon to produce compound semiconductors.

Photolithographic techniques to maximise the area used on the wafer and reduce the dimensions of interconnections.

Deposition techniques to transfer donor material onto wafers, such as Atomic Layer Deposition (ALD) and Radio Frequency (RF) magnetron sputtering.

Increasing placement accuracy – active alignment techniques.

New base materials for building and growing semiconductors on ceramic/Teflon/diamond substrates.

Multi-chip modules and System in Package applications.

Modification of electrical properties on chips.

Packaging, flex circuits, stacked dies, and Flip chip/Ball Grid Array (BGA) chip developments.

### LO4 **Evaluate the commercial viability of emerging semiconductor technologies**

*The global market place:*

Changing markets, design and manufacturing sectors. Growth in demand. Competition. Life cycle. Intellectual Property Rights (IPR). General trends computing; communication, data. National and international supply chains and logistics. Innovation, enterprise and skill development.

Commercial awareness of trends and global investment in the semiconductor market.

### *Emerging and developing markets*

New and innovative areas for commercial development aided by emerging semiconductor devices, e.g., Big Data Analytics, Internet of Things (IoT), entertainment, leisure, artificial intelligence (AI), finance, voting applications.

Medical implants, research, testing, and health monitoring.

Bio-engineering.

Super miniaturisation, e.g., gaming, mobile phones.

Agriculture (food production).

Global warming.

Automatic transportation systems (cars, railway, aviation, shipping). Space exploration.

Automatic control of services to improve battery efficiency in electric cars, automobile charging of batteries, distribution and storage control of wind and solar power sources.

Military, security, and tracking applications.

Safety and reducing risk.

Photoelectric and lighting applications.

## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<b>L01</b> Investigate the properties of emerging semiconductor materials		<b>D1</b> Evaluate the characteristics of compound silicon devices.
<b>P1</b> Review the properties of a range of emerging semiconductor materials.	<b>M1</b> Compare the characteristics of a silicon PN power diode when compared to those of silicon carbide.	
<b>L02</b> Research new trends and applications for emerging semiconductor technologies		<b>D2</b> Research into how the developing needs of industry and commerce inform and drive the development of new semiconductor devices.
<b>P2</b> Discuss how areas such as medicine and automotive engineering may create new demands and opportunities in the semiconductor industry.	<b>M2</b> Assess suitability and limitations of different types of semiconductors in emerging application areas.	
<b>L03</b> Analyse the requirements and equipment used in emerging semiconductor technologies		<b>D3</b> Evaluate the techniques used to process silicon carbide with silicon to produce a compound semiconductor.
<b>P3</b> Describe how photolithographic techniques have been developed to meet the demands of accuracy and increase density of devices on a chip.	<b>M3</b> Investigate the methods used to grow semiconductor circuits on different substrate materials.	
<b>P4</b> Discuss the methods used for packaging individual silicon dies for use on a flex circuit board and a System in Package application.		
<b>L04</b> Evaluate the commercial viability of emerging semiconductor technologies		<b>D4</b> Analyse how the semiconductor industry manages the life cycle of products.
<b>P5</b> Investigate the current market demand for semiconductor devices.	<b>M4</b> Evaluate how the semiconductor industry gathers information on emerging needs from different industrial sectors- e.g. automotive, medical, gaming, and mobile phone.	

## Recommended Resources

### Textbooks

GENG, H. (2017) *Semiconductor Manufacturing Handbook*, Second Edition. McGraw Hill Professional.

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

MAY, G. and SPANOS, C. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. John Wiley & Sons, Inc.

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

### Websites

semiconductors.org                      Semiconductor Industry Association  
(General reference)

advancedenergy.com                      Trends impacting the semiconductor  
industry in the next three years  
(General reference)

### Links

This unit links to the following related units:

*Unit 20: Digital Principles*

*Unit 22: Electronic Circuits and Devices*

*Unit 52: Further Electrical, Electronic and Digital Principles*

# Unit 87: Semiconductor Integrated Electronics

**Unit code** D/618/1766

**Unit level** 5

**Credit value** 15

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## Introduction

Almost every aspect of our lives is affected by semiconductor devices. These devices are produced in their millions and are often seemingly invisible to their users. Although each device may only use small amounts of electrical energy, collectively they use an enormous amount of power. This unit investigates the characteristics of semiconductor devices and how they are integrated in applications such as digital systems, control, instrumentation, optical and communication networks that are in common use.

The physical structure of semiconductor devices is crucial to the understanding of their behaviour and how these parameters may be changed to meet the demands of different applications. This will allow the student to understand why different choices are made to arrive at the correct and most efficient processes to meet the need of the customer.

On successful completion of this unit students will be able to address complex semiconductor manufacturing processes resulting in the production of reliable and efficient electronic power devices.

## Learning Outcomes

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

1. Review the characteristics of semiconductor devices and how their physical structure varies in manufacture to produce the separate elements for integration into a complex integrated circuit
2. Investigate how common analogue and digital integrated circuits can be developed using basic active and passive elements, to produce single chip solutions
3. Investigate how adaptations to the semiconductor physical layers allow these devices to be used in a wide range of applications
4. Evaluate how semiconductor technologies and processes can produce reliable and efficient electronic power devices.

## Essential Content

### LO1 **Review the characteristics of semiconductor devices and how their physical structure varies in manufacture to produce the separate elements for integration into a complex integrated circuit**

#### *Structure and characteristics of semiconductors*

Forming Insulators and conductors in silicon.

Forming semiconductor junctions, creating Positive Negative (PN) junctions and Positive Negative Positive (PNP) and Negative Positive Negative (NPN) devices.

Bipolar junction transistor families and their characteristics and limitations.

Creating integrated electronic circuits.

#### *Metal-Oxide-Semiconductor Technology*

Metal-Oxide-Semiconductor (MOS) families; Positive Metal-Oxide-Semiconductor (PMOS), Negative Metal-Oxide-Semiconductor (NMOS) and Complementary Metal-Oxide-Semiconductor (CMOS) and their characteristics.

Fabrication of MOS devices; Field effect devices (MOSFET).

Comparison of Bipolar and MOS devices.

### LO2 **Investigate how common analogue and digital integrated circuits can be developed using basic active and passive elements (resistors, capacitors, diodes and transistors), to produce single chip solutions**

#### *Analogue and digital integrated circuits*

Analogue integrated circuits (IC's), their characteristics, and limitations.

Interconnecting different cells of an IC to the metal lead frame using metal-evaporation and sputtering.

Digital integrated circuits, different characteristics and limitations. Logic devices and microprocessor devices.

Integrating analogue and digital elements; System on chip solutions, Microcontroller Unit (MCU) and embedded systems.

**LO3 Discuss how adaptations to the semiconductor physical layers allow these devices to be used in a wide range of applications**

*Modifications in processing technology to enhance chip performance for various applications.*

Developments in manufacturing process introduced to meet technical demands of new products. Adapting the manufacturing process to increase system performance in areas of Radio frequency and high-speed (memory) processing applications. Effect of changing the following aspects of semiconductor fabrication; physical dimensions of internal connectors, size of die, etching, doping, diffusion, materials, and ionic implantation.

Manufacturing processes to create semiconductor devices for the photo-electric and optical industries. Visible light emitting diodes (VLED) or light emitting diode (LED); Infrared light emitting diode (ILED); light sensitive devices; liquid crystal displays; Laser diodes and solar cells.

**LO4 Evaluate how Semiconductor Technologies and processes can produce reliable and efficient electronic power devices**

*Physical limitations of semiconductor materials.*

Thermo-electric breakdown, conductivity modulation, electrical spatial current instability, physical dimensions, and packaging. Switching speed.

Different levels of complexity; phenomenological, analytical and numerical simulation. Local structure defects, physical safe operating levels (Voltage, Current and Power). Catastrophic failures. Environmental effects on reliability of Integrated circuits (ICs). Reliability assurance, safe operating area and electrostatic discharges (ESD). Methods of mitigating potential failures in ICs caused by exceeding safe operating levels.

Semiconductor power devices, e.g., Silicon Controlled Rectifiers (SCR), power Metal Oxide Semiconductor Field Effect Transistors (MOSFETS), Insulated Gate Bipolar Transistors (IGBT).



## Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
<p><b>LO1</b> Review the characteristics of semiconductor devices and how their physical structure varies in manufacture to produce a complex integrated circuit</p>		<p><b>D1</b> Review the techniques for manufacturing a CMOS device that enables simplification of integrated circuit design.</p>
<p><b>P1</b> Explore the characteristics of semiconductor devices and how their physical structure varies in manufacture</p> <p><b>P2</b> Describe how an integrated circuit could be formed using MOS devices</p>	<p><b>M1</b> Compare the differences in characteristics between bipolar and MOS devices when used in an integrated circuit.</p>	
<p><b>LO2</b> Investigate how basic active and passive elements can be used to produce single chip solutions</p>		<p><b>D2</b> Review the technical issues when combining analogue and digital systems as found on MCU devices</p>
<p><b>P3</b> Describe how electronic circuits can be developed using active and passive semiconductor elements.</p>	<p><b>M2</b> Explain how individual semiconductor cells forming an integrated circuit can be connected to the supporting lead frame.</p>	
<p><b>LO3</b> Discuss how adaptations to the semiconductor physical layers allow circuits to be used in a wide range of applications</p>		<p><b>D3</b> Critically analyse how semiconductor manufacturing processes have had to be changed to be able to produce integrated devices for the mobile phone industry.</p>
<p><b>P4</b> Explore how adaptations to the semiconductor physical layers allows circuits to be used in a wide range of applications</p> <p><b>P5</b> Investigate how the physical structure of a silicon capacitor made from a PN junction effects bandwidth and high frequency operation.</p>	<p><b>M3</b> Discuss the principles supporting the operational characteristics of a light emitting diode (LED) and an infra-red LED.</p>	

Pass	Merit	Distinction
<p><b>LO4</b> Evaluate how semiconductor technologies and processes can produce reliable and efficient electronic power devices</p>		<p><b>D4</b> Critically evaluate the manufacturing techniques necessary to improve the reliability of an integrated circuit.</p>
<p><b>P7</b> Explore how semiconductor technologies and processes can produce reliable and efficient electronic power devices</p> <p><b>P8</b> Explain the problems caused by increasing the switching speed of a programmable logic device.</p> <p><b>P9</b> Discuss typical safe operating and environment conditions when manufacturing an integrated circuit.</p>	<p><b>M4</b> Assess how semiconductor devices may be protected from electrostatic discharges.</p>	

## Recommended Resources

### Textbooks

GENG, H. (2017) *Semiconductor Manufacturing Handbook*, Second Edition. McGraw Hill Professional.

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

MAY, G. and SPANOS, C. (2006) *Fundamentals of Semiconductor Manufacturing and Process Control*. John Wiley & Sons, Inc.

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

### Links

This unit links to the following related units:

*Unit 20: Digital Principles*

*Unit 22: Electronic Circuits and Devices*

*Unit 52: Further Electrical, Electronic and Digital Principles*

# 11 Appendices

## Appendix 1: Mapping of HND in Engineering against FHEQ Level 5

Key	
KU	Knowledge and Understanding
CS	Cognitive Skills
AS	Applied Skills
TS	Transferable Skills

The qualification will be awarded to students who have demonstrated:

FHEQ Level 5 descriptor		Engineering HND Programme Outcome
Knowledge and critical understanding of the well-established principles of their area(s) of study, and of the way in which those principles have developed.	KU1	Knowledge and understanding of the fundamentals principles and practices of the contemporary global engineering industry.
	KU2	Knowledge and understanding of the external engineering environment and its impact upon local, national and global levels of strategy, behaviour, management and sustainability.
	KU3	Understanding and insight into different engineering practices, their diverse nature, purposes, structures and operations and their influence upon the external environment.
	KU4	A critical understanding of the ethical, environmental, legal, regulatory, professional and operational frameworks within which engineering operates.
	KU5	A critical understanding of process, practices and techniques for effective management of products, processes, services and people.
	KU6	A critical understanding of the evolving concepts, theories and models within the study of engineering across the range of operational alternatives.

FHEQ Level 5 descriptor		Engineering HND Programme Outcome
	KU7	An ability to evaluate and analyse a range of concepts and theories, models and techniques to make appropriate engineering operational and management decisions.
	KU8	An appreciation of the concepts and principles of CPD, staff development, team dynamics, leadership and reflective practice as strategies for personal and people development.
	KU9	Knowledge and understanding of how the key areas of engineering and the environment it operates within influence the development of people and businesses.
	KU10	An understanding of the skills, techniques and methodologies used to resolve problems in the workplace.
	KU11	Knowledge and understanding of the human-machine interaction to inform the development of good design and fitness for purpose.

FHEQ Level 5 descriptor		Engineering HND Programme Outcome
Ability to apply underlying concepts and principles outside the context in which they were first studied, including, where appropriate, the application of those principles in an employment context.	CS1	Apply knowledge and understanding of essential concepts, principles and models within the contemporary global engineering industry.
	AS1	Evidence the ability to show customer relationship management skills and develop appropriate policies and strategies to meet stakeholder expectations.
	AS2	Apply innovative engineering ideas to design and develop new products or services that respond to the changing nature of the engineering industry and the global market.
	AS3	Integrate theory and practice through the investigation, evaluation and development of practices and products in the workplace.
	AS4	Develop outcomes for customers using appropriate practices and data to make justified recommendations.
	CS2	Develop different strategies and methods to show how resources (human, financial, environmental and information) are integrated and effectively managed to successfully meet objectives.
Knowledge of the main methods of enquiry in the subject(s) relevant to the named award, and ability to evaluate critically the appropriateness of different approaches to solving problems in the field of study.	CS3	Critically evaluate current principles and operational practices used within the engineering industry as applied to problem-solving.
	CS4	Apply project management skills and techniques for reporting, planning, control and problem-solving.
	CS5	Recognise and critically evaluate the professional, economic, social, environmental and ethical issues that influence the sustainable exploitation of people, resources and businesses.
	CS6	Critique a range of engineering information technology systems and operations and their application to maximise and successfully meet strategic objectives.
	KU12	An ability to deploy processes, principles, theories, skills and techniques to analyse, specify, build and evaluate processes and outcomes.

<b>FHEQ Level 5 descriptor</b>		<b>Engineering HND Programme Outcome</b>
An understanding of the limits of their knowledge, and how this influences analysis and interpretations based on that knowledge.	TS1	Develop a skill-set to enable the evaluation of appropriate actions taken for problem-solving in specific engineering contexts
	TS2	Develop self-reflection, including self-awareness, to become an effective self-managing student, appreciating the value and importance of the self-reflection process.
	TS3	Undertake independent learning to expand on own skills and delivered content.

Typically, holders of the qualification will be able to:

<b>FHEQ Level 5 descriptor</b>		<b>Engineering HND Programme Outcomes</b>
Use a range of established techniques to initiate and undertake critical analysis of information, and to propose solutions to problems arising from that analysis.	TS4	Competently use digital literacy to access a broad range of research sources, data and information.
	CS7	Interpret, analyse and evaluate a range of engineering data, sources and information to inform evidence-based decision-making.
	CS8	Synthesise knowledge and critically evaluate strategies and plans to understand the relationship between theory and actual world engineering situations.
Effectively communicate information, arguments and analysis in a variety of forms to specialist and non-specialist audiences, and deploy key techniques of the discipline effectively.	TS5	Communicate confidently and effectively, both orally and in writing both internally and externally with engineering professionals and other stakeholders.
	TS6	Demonstrate strong interpersonal skills, including effective listening and oral communication skills, as well as the associated ability to persuade, present, pitch and negotiate.



<b>FHEQ Level 5 descriptor</b>		<b>Engineering HND Programme Outcome</b>
Undertake further training, develop existing skills and acquire new competences that will enable them to assume significant responsibility within organisations.	TS7	Identify personal and professional goals for continuing professional development in order to enhance competence to practice within a chosen engineering field.
	TS8	Take advantage of available pathways for continuing professional development through Higher Education and Professional Body Qualifications.

Holders will also have:

<b>FHEQ Level 5 descriptor</b>		<b>Engineering HND Programme Outcomes</b>
The qualities and transferable skills necessary for employment requiring the exercise of personal responsibility and decision-making.	TS9	Develop a range of skills to ensure effective team working, project and time management, independent initiatives, organisational competence and problem-solving strategies.
	TS10	Reflect adaptability and flexibility in approach to engineering; showing resilience under pressure and meeting challenging targets within given deadlines.
	TS11	Use quantitative skills to manipulate data, evaluate and verify existing theory.
	CS9	Evaluate the changing needs of the engineering industry and have the confidence to self-evaluate and undertake additional CPD as necessary.
	TS12	Develop emotional intelligence and sensitivity to diversity in relation to people, cultures and environments.
	TS13	Show awareness of current developments within the engineering industry and their impact on employability and CPD.

## Appendix 2: HNC/HND Engineering Programme Outcomes for Learners

Unit	Knowledge and Understanding											Cognitive skills									Applied skills				Transferable skills											
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12
1	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X
2	X										X							X				X		X			X									
3	X										X							X				X		X			X									
4	X	X	X	X	X	X	X	X	X	X											X	X		X		X					X	X	X	X	X	X
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
6	X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X						X	X	
7	X	X	X							X	X	X					X							X												
8	X																					X														
9	X								X									X				X		X			X									
10	X										X							X				X		X												
11	X																					X														
12	X								X													X		X												
13	X	X	X	X	X	X	X									X	X				X			X							X		X	X	X	
14	X										X						X				X			X		X										
15	X					X	X										X								X											
16	X			X	X					X						X	X										X					X				

Unit	Knowledge and Understanding											Cognitive skills									Applied skills				Transferable skills															
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12				
17	X																X								X		X							X						
18	X	X	X	X	X	X	X		X	X	X						X	X				X	X	X	X		X								X					
19	X	X	X		X	X	X		X	X														X										X		X		X		
20	X																																							
21	X										X											X	X													X				
22	X																X																				X			
23	X	X	X				X			X		X											X	X											X		X		X	
24	X										X											X	X														X			
25	X																	X																				X		
26	X										X											X	X															X		
27	X																							X	X													X		
28	X										X												X															X		
29	X										X							X																				X		
30	X	X	X		X		X			X								X					X		X											X	X	X		
31	X										X			X				X					X		X		X								X		X		X	
32	X	X	X				X				X		X				X	X					X	X			X								X		X		X	
33	X	X	X				X				X		X				X	X					X	X			X									X		X		X
34	X	X	X	X	X	X	X					X																										X		X

Unit	Knowledge and Understanding											Cognitive skills									Applied skills				Transferable skills															
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12				
35	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X		X	X	X	X		X		X	X	X	X	X	X	X	X	X		
36	X	X	X	X	X	X	X	X		X			X	X	X	X		X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X		
37	X						X					X											X												X		X			
38	X	X	X			X	X			X														X			X					X			X					
39	X											X					X						X		X			X								X				
40	X											X					X						X		X			X								X				
41	X																X										X									X		X		
42	X													X									X	X												X				
43	X																X											X									X			
44	X													X									X	X													X			
45	X						X										X											X									X			
46	X					X																						X										X		
47	X																X						X	X													X			
48	X											X																X										X		
49	X	X	X		X	X	X												X		X	X	X	X											X		X		X	
50	X	X	X	X	X	X	X		X	X	X		X		X				X		X	X	X	X					X	X					X		X		X	
51	X	X	X		X	X	X						X		X	X			X				X														X		X	
52	X	X	X	X	X	X	X	X	X	X			X	X		X	X		X	X	X		X	X	X	X				X					X		X	X	X	

Unit	Knowledge and Understanding											Cognitive skills									Applied skills				Transferable skills																
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12					
53	X											X						X																			X				
54	X	X	X		X	X	X																X		X													X			
55	X											X		X					X																			X			
56	X											X							X				X														X		X		
57	X											X											X															X			
58	X											X											X															X			
59	X											X							X				X															X			
60	X											X											X															X			
61	X											X													X													X			
62	X											X											X															X			
63	X			X							X								X				X															X			
64	X	X	X	X	X	X	X		X	X			X		X				X				X		X	X										X	X	X			
65	X											X																										X		X	
66	X	X	X	X	X	X	X						X			X			X	X			X		X													X		X	
67	X	X	X	X																			X		X				X		X							X			
68	X											X							X				X		X												X		X		
69	X	X	X									X							X				X		X													X	X	X	
70	X				X	X	X					X		X	X				X				X		X												X	X	X		X

Unit	Knowledge and Understanding											Cognitive skills									Applied skills				Transferable skills											
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	7	8	9	10	11	12
71	X	X	X	X	X	X	X				X	X		X	X							X	X	X					X		X	X	X		X	
72	X	X	X	X	X	X	X				X		X	X	X	X		X	X		X	X	X	X	X	X	X	X				X	X	X		
73			X	X	X		X			X		X		X			X						X			X										
74					X	X	X			X		X		X			X					X	X	X	X										X	
75	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	
76	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
77	X					X	X										X									X										
78	X					X	X										X									X										
79	X	X	X				X				X		X			X	X						X	X			X				X		X		X	
80	X											X					X							X	X											
81	X									X		X					X						X			X			X							
82	X		X		X		X					X	X	X	X		X						X	X		X	X			X					X	
83	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
84	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
85	X		X	X	X		X	X		X	X		X	X		X	X	X				X	X		X	X	X		X	X	X	X		X	X	
86	X		X	X	X	X		X	X		X		X	X		X		X				X	X	X		X	X		X	X	X	X		X	X	X
87	X		X	X		X	X			X	X	X		X	X		X	X		X	X		X	X	X	X		X	X	X		X	X	X		X

## Appendix 3: Pearson BTEC Level 5 Higher National Diploma in Engineering: mapping of transferable employability and academic study skills

Skill Sets	Cognitive skills							Intra-personal Skills				Interpersonal Skills			
	Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan Prioritise	Self Management	Independent learning	Self Reflection	Team Work	Leadership	Cultural Awareness
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X		X	X	X			X	X					
3	X	X		X	X	X			X	X					
4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	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
7	X	X	X			X	X	X	X	X	X	X	X		
8	X						X	X	X	X	X				
9	X	X		X	X	X			X	X					
10	X	X	X			X	X	X	X	X					
11	X						X	X	X	X	X				
12	X	X		X	X	X			X	X					
13	X	X	X	X				X	X	X	X	X	X	X	X
14	X	X		X	X	X			X	X					
15	X						X	X	X	X	X				

Skill Sets	Cognitive skills							Intra-personal Skills				Interpersonal Skills			
	Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan Prioritise	Self Management	Independent learning	Self Reflection	Team Work	Leadership	Cultural Awareness
16	X	X	X			X	X		X	X	X	X			
17	X	X	X			X	X		X	X	X	X			
18	X	X	X	X		X	X	X	X	X	X	X	X	X	
19	X	X	X	X		X	X		X	X	X	X	X		
20	X	X	X			X	X		X	X	X	X			
21	X	X	X			X	X		X	X	X	X			
22	X	X	X			X	X		X	X	X	X			
23	X	X	X	X		X	X	X	X	X	X	X	X		
24	X	X				X	X				X	X			
25	X	X				X	X				X	X			
26	X	X				X	X				X	X			
27	X	X	X	X			X	X	X	X	X	X			
28	X	X				X	X				X	X			
29	X	X		X		X	X			X	X				
30	X	X	X	X		X	X	X	X	X	X	X	X	X	
31	X	X	X			X	X		X	X	X	X			
32	X	X	X	X		X	X	X	X	X	X	X	X		
33	X	X	X			X	X		X	X	X	X	X		
34	X	X	X	X		X	X	X	X	X	X	X			X



Skill Sets	Cognitive skills							Intra-personal Skills				Interpersonal Skills		
	Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan Prioritise	Self Management	Independent learning	Self Reflection	Team Work	Leadership
35	X	X	X	X	X	X	X	X	X	X	X	X	X	X
36	X	X			X	X		X	X	X	X			
37	X	X			X	X		X	X	X	X			
38	X	X			X	X		X	X	X	X			
39	X	X	X	X	X	X		X	X	X	X			
40	X	X	X	X	X	X	X	X	X	X	X	X		
41	X	X	X		X	X		X	X	X	X			
42	X	X	X		X	X		X	X	X	X			
43	X	X	X		X	X		X	X	X	X			
44	X	X	X		X	X		X	X	X	X			
45	X	X	X		X	X		X	X	X	X			
46	X	X	X		X	X		X	X	X	X			
47	X	X	X		X	X		X	X	X	X			
48	X	X	X	X	X	X	X	X	X	X	X	X	X	
49	X	X	X	X	X	X	X	X	X	X	X	X	X	
50	X	X	X	X	X	X	X	X	X	X	X	X	X	
51	X	X	X	X	X	X	X	X	X	X	X	X	X	
52	X	X	X	X	X	X	X	X	X	X	X	X	X	
53	X	X	X	X		X	X	X	X	X	X	X	X	

Skill Sets	Cognitive skills							Intra-personal Skills				Interpersonal Skills			
	Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan Prioritise	Self Management	Independent learning	Self Reflection	Team Work	Leadership	Cultural Awareness
54	X	X	X			X	X		X	X	X	X			
55	X	X	X			X	X		X	X	X	X			
56	X	X	X			X	X		X	X	X	X			
57	X	X				X	X		X	X	X	X			
58	X	X				X	X		X	X	X	X			
59	X	X				X	X		X	X	X	X			
60	X	X				X	X		X	X	X	X			
61	X	X				X	X		X	X	X	X			
62	X	X	X	X		X		X	X	X	X	X	X		
63	X	X				X	X		X	X	X	X			
64	X	X	X			X	X		X	X	X	X	X		
65	X	X	X	X	X	X	X		X	X	X	X	X		X
66	X	X		X		X	X			X	X				
67	X	X				X	X		X	X	X	X	X		
68	X	X				X	X		X	X	X	X	X		
69	X	X	X	X		X	X	X	X	X	X	X	X		
70	X	X				X	X		X	X	X	X	X		
71	X	X				X	X		X	X	X	X	X		
72	X	X	X	X		X		X	X	X	X	X			

Skill Sets	Cognitive skills							Intra-personal Skills				Interpersonal Skills		
	Unit	Problem Solving	Critical Thinking/ Analysis	Decision Making	Effective Communication	Digital Literacy	Numeracy	Creativity	Plan Prioritise	Self Management	Independent learning	Self Reflection	Team Work	Leadership
73	X	X	X			X				X	X			
74	X	X	X	X		X				X				
75	X	X	X	X	X		X	X	X	X	X	X		X
76	X	X	X	X			X	X	X	X	X	X	X	X
77	X	X	X	X	X	X	X	X	X			X		
78	X	X	X	X	X	X	X	X	X			X		
79	X	X	X	X	X	X	X	X	X	X	X	X		X
80	X	X	X			X	X	X	X	X	X	X		
81	X	X	X	X	X	X		X	X	X	X	X		
82	X	X	X	X	X	X		X		X		X		
83	X	X	X		X	X		X		X		X		
84	X	X	X	X	X	X		X	X		X	X	X	
85	X	X	X	X	X	X		X		X		X	X	
86	X	X	X	X	X	X	X	X	X	X		X	X	
87	X	X	X	X	X	X	X	X	X	X		X	X	

## Appendix 4: Glossary of command verbs used for internally assessed units

This is a summary of the key terms used to define the requirements within units.

Term	Definition
Analyse	<p>Present the outcome of methodical and detailed examination either:</p> <ul style="list-style-type: none"> <li>• breaking down a theme, topic or situation in order to interpret and study the interrelationships between the parts; and/or</li> <li>• of information or data to interpret and study key trends and interrelationships.</li> </ul> <p>Analysis can be through activity, practice, written or verbal presentation.</p>
Apply	<p>Put into operation or use.</p> <p>Use relevant skills/knowledge/understanding appropriate to context.</p>
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	<p>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.</p> <p>This is used to show depth of knowledge through selection of characteristics.</p>
Compose	Create or make up or form.
Communicate	<p>Convey ideas or information to others.</p> <p>Create/construct Skills to make or do something, for example a display or set of accounts.</p>
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.

<b>Term</b>	<b>Definition</b>
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.
Discuss	Consider different aspects of: <ul style="list-style-type: none"> <li>• a theme or topic;</li> <li>• how they interrelate; and</li> <li>• the extent to which they are important.</li> </ul>
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: <ul style="list-style-type: none"> <li>• strengths or weaknesses</li> <li>• advantages or disadvantages</li> <li>• alternative actions</li> <li>• relevance or significance</li> </ul> <p>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.</p>
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.

<b>Term</b>	<b>Definition</b>
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: <ul style="list-style-type: none"> <li>• support an opinion; or</li> <li>• show something to be right or reasonable.</li> </ul>
Outline	Set out the main points/characteristics.
Plan	Consider, set out and communicate what is to be done.
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: <ul style="list-style-type: none"> <li>• appraise existing information or prior events</li> <li>• reconsider information with the intention of making changes, if necessary.</li> </ul>
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 Pearson 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 5: Assessment Methods and Techniques for Higher Nationals

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Academic graphic display	This technique asks students to create documents providing well-presented information for a given purpose. Could be hard or soft copy.	Creativity	Formative
		Written Communication	Summative
		Information and Communications Technology	
		Literacy	
Case Study	This technique present students with a specific example to which they must select and apply knowledge.	Reasoning	Formative
		Critical Thinking	Summative
		Analysis	
Discussion Forum	This technique allows students to express their understanding and perceptions about topics and questions presented in the class or digitally, for example online groups, blogs.	Oral/written Communication	Formative
		Appreciation of Diversity	
		Critical Thinking and Reasoning	
		Argumentation	
Examination	This technique covers all assessment that needs to be done within a centre-specified time constrained period on-site. Some units may be more suited to an exam-based assessment approach, to appropriately prepare students for further study such as progression on to Level 6 programmes or to meet professional recognition requirements.	Reasoning	Summative
		Analysis	
		Written Communication	
		Critical Thinking	
		Interpretation	



Assessment Technique	Description	Transferable Skills Development	Formative or Summative
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	
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.	

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
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	
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	

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Team Assessment	This technique asks students to work together to show skills in defining and structuring an activity as a team. All team assessment should be distributed equally, each of the group members performing their role, and then the team collates the outcomes, and submits it as a single piece of work.	Collaboration	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	
Written Task or Report	This technique asks students to complete an assignment in a structured written format, for example, a project plan, a report, marketing communication, set of instructions, giving information.	Reasoning	Summative
		Analysis	
		Written Communication	
		Critical Thinking	
		Interpretation	

## Appendix 6: Recognition of Prior Learning

**QCF Pearson BTEC Level 4 Higher National Certificate in Engineering unit content mapped to the Level 4 units available in the Pearson BTEC Higher National Engineering programmes (RQF)**

### HNCs in Engineering: Unit Mapping Overview

This mapping document is designed to support centres who wish to recognise student achievement in older QCF Higher Nationals within the new RQF suites. The document demonstrates where content is covered in the new suite, and where there is new content to cover to ensure full coverage of learning outcomes.

P – Partial mapping (some topics from the old unit appear in the new unit)

X – Full mapping + new (all the topics from the old unit appear in the new unit, but new unit also contains new topic(s))

N – New unit

Unit no.	Unit title New RQF HN programme	Maps to unit number on existing QCF HN programme	Level of similarity between units
1	Engineering Design	8	P
2	Engineering Maths	1	P
3	Engineering Science	2	X
4	Managing a Professional Engineering Project		New Unit
5	Renewable Energy		New Unit
6	Mechatronics	57	P
7	Machining and Metal Forming Processes	10	P
8	Mechanical Principles	4	P
9	Materials, Properties and Testing	21	P
10	Mechanical Workshop Practices	13	P
11	Fluid Mechanics	41	X
12	Engineering Management	38	P
13	Fundamentals of Thermodynamics and Heat Engines	61	P

Unit no.	Unit title New RQF HN programme	Maps to unit number on existing QCF HN programme	Level of similarity between units
14	Production Engineering for Manufacture	9	P
15	Automation, Robotics and PLCs	22	P
		32	P
16	Instrumentation and Control Systems	55	P
17	Quality and Process Improvement	20	P
		30	P
		36	P
18	Maintenance Engineering	43	P
		44	P
		54	P
19	Electrical and Electronic Principles	5	X
20	Digital Principles		N
21	Electrical Machines	65	P
22	Electronic Circuits and Devices	39	P
23	Computer Aided Design and Manufacture (CAD/CAM)	19	X
24	Aircraft Aerodynamics	83	X
25	Aircraft Electrical Power & Distribution Systems	82	
26	Airframe Mechanical Systems		N
27	Composite Materials for Aerospace Applications		N
28	Turbine Rotary Wing Mechanical and Flight Systems		N
29	Electro, Pneumatic and Hydraulic Systems	24	P
30	Operations and Plant Managements	45	P
		46	P
		47	P
31	Electrical Systems and Fault Finding		N
32	CAD for Maintenance Engineers		N

<b>Unit no.</b>	<b>Unit title New RQF HN programme</b>	<b>Maps to unit number on existing QCF HN programme</b>	<b>Level of similarity between units</b>
73	Materials Engineering with Polymers	155	X
74	Polymer Manufacturing Processes	156	X
75	Industry 4.0		N
76	Introduction to Professional Engineering Management		N
77	Industrial Robots		N
78	Programmable Logic Controllers		N
79	Computer Aided Design (CAD) for Engineering		N
80	Welding Technology	154	X
81	Welding Inspection	153	X
82	Statistical Process Control		N
83	Telecommunication Principles		N
84	Semiconductor Manufacture		N
85	Emerging Semiconductor Technologies		N

## HNCs in Engineering: Unit Mapping Depth

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
1	Engineering Design	8	Engineering Design	Unit 8: LO1 Unit 8: LO2 Unit 8: LO3 No Match	Unit 1: LO1 Unit 1: LO2 Unit 1: LO3 Unit 1: LO4 No match
2	Engineering Maths	1	Analytical Methods for Engineers	Unit 1: LO2 Unit 1: LO3 Unit 1: LO4	Unit 2: LO1 No match Unit 2: LO3 Unit 2: LO4 Unit 2: LO2
3	Engineering Science	2	Engineering Science	Unit 2: LO1/2 Unit 2: LO3/4	Unit 3: LO2 Unit 3: LO4 Unit 3: LO1 No match Unit 3: LO3 No match
4	Managing a Professional Engineering Project		New unit, no equivalent		
5	Renewable Energy		New unit, no equivalent		
6	Mechatronics	57	Mechatronics	Unit 57: LO1 Unit 57: LO3	Unit 6: LO1 Unit 6: LO3 No match Unit 6: LO2 Unit 6: LO4 No match
7	Machining and Metal Forming Processes	10	Manufacturing Process	Unit 10: LO1 Unit 10: LO2	Unit 7: LO1 Unit 7: LO4 Unit 7: LO2 No match Unit 7: LO3 No match
8	Mechanical Principles	4	Mechanical Principles	Unit 4: LO2 Unit 4: LO3 Unit 4: LO4	Unit 8: LO1 Unit 8: LO2 No match Unit 8: LO3/4 Unit 8: LO3/4

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
9	Materials, Properties and Testing	21	Materials Engineering	Unit 21: LO1 Unit 21: LO2 Unit 21: LO3 Unit 21: LO4	Unit 9: LO2 No match Unit 9: LO3 Unit 9: LO1 Unit 9: LO4
10	Mechanical Workshop Practices	10	Manufacturing Process	Unit 10: LO1	Unit 10: LO2 Unit 10: LO1 No match Unit 10: LO3 No match Unit 10: LO4 No match
11	Fluid Mechanics	41	Fluid Mechanics	Unit 41: LO1 Unit 41: LO2 Unit 41: LO3 Unit 41: LO4	Unit 11: LO1 Unit 11: LO2 Unit 11: LO3 Unit 11: LO4
12	Engineering Management	38	Managing People in Engineering	Unit 38: LO1/2 Unit 38: LO3	Unit 12: LO1 Unit 12: LO2 Unit 12: LO3 No match Unit 12: LO4 No match
13	Fundamentals of Thermodynamics and Heat Engines	61	Engineering Thermodynamics	Unit 61: LO1 Unit 61: LO2 Unit 61: LO4	Unit 13: LO1 Unit 13: LO4 Unit 13: LO3 No match Unit 13: LO2
14	Production Engineering for Manufacture	9	Manufacturing Planning and Scheduling Principles	Unit 9: LO1 Unit 9: LO4	Unit 14: LO1 Unit 14: LO2 Unit 14: LO3 No match Unit 14: LO4 No match
15	Automation, Robotics and PLCs	22 & 32	Programmable Logic Controllers (22) and Industrial Robot Technology (32)	Unit 22: LO1 Unit 32: LO2 Unit 22: LO2 Unit 32: LO3	Unit 15: LO1 Unit 15: LO2 Unit 15: LO3 Unit 15: LO4



RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
16	Instrumentation and Control Systems	55	Instrumentation and Control Systems	Unit 55: LO1 Unit 55: LO2	Unit 16: LO1 Unit 16: LO1 & LO2  Unit 16: LO 3 No match  Unit 16: LO4 No match:
17	Quality and Process Improvement	20, 30 & 36	Quality & Business Improvement (20), Quality Assurance & Management (30) and Statistical Process Control (36)	Unit 36: LO1  Unit 20: LO2 & Unit 30: LO2	Unit 17: LO1 Unit 17: LO2 No match  Unit 17: LO3 No match  Unit 17: LO4
18	Maintenance Engineering	44, 45	Plant Maintenance and Decommissioning (44), Plant Operations and Performance (45)	Unit 45: LO 1/2  Unit 44: LO1/2  Unit 44: LO3	Unit 18: LO1  Unit 18: LO2 Unit 18: LO3 No Match  Unit 18: LO4
19	Electrical and Electronic Principles	5	Electrical and Electronic Principles	Unit 5: LO3	Unit 19: LO1 No match  Unit 19: LO2 Unit 19: LO3 No match  Unit 19: LO4 No match
20	Digital Principles		New unit, no equivalent		
21	Electrical Machines	65	Utilisation of Electrical Energy	Unit 65: LO1  Unit 65: LO5	Unit 21: LO1  Unit 21: LO2 Unit 21: LO3 No Match  Unit 21: LO4 No match
22	Electronic Circuits and Devices	39	Electronic Principles	Unit 39: LO2  Unit 39: LO3  Unit 39: LO4	Unit 22: LO1  Unit 22: LO2  Unit 22: LO3 Unit 22: LO4 No match
23	Computer Aided Design and Manufacture (CAD/ CAM)	19	Computer-aided Design and Manufacture	Unit 19: LO1  Unit 19: LO2  Unit 19: LO3	Unit 23: LO1  Unit 23: LO2  Unit 23: LO3 Unit 23: LO4 No match

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
24	Aircraft Aerodynamics	83	Aerodynamic Principles and Aircraft Design	Unit 83: LO1 Unit 83: LO2 Unit 83: LO3 Unit 83: LO4	Unit 24: LO1 Unit 24: LO2 Unit 24: LO3 Unit 24: LO4
25	Aircraft Electrical Power & Distribution Systems	82	Aircraft Systems Principles and Applications	Unit 82: LO2	Unit 25: LO1 No match Unit 25: LO2 Unit 25: LO3 No match Unit 25: LO4 No match
26	Airframe Mechanical Systems		New unit, no equivalent		
27	Composite Materials for Aerospace Applications		New unit, no equivalent		
28	Turbine Rotary Wing Mechanical and Flight Systems		New unit, no equivalent		
29	Electro, Pneumatic and Hydraulic Systems	24	Applications of Pneumatics and Hydraulics	Unit 24: LO1 Unit 24: LO3	Unit 29: LO1 No match Unit 29: LO2 Unit 29: LO3 Unit 29: LO4 No match
30	Operations and Plant Managements		New unit, no equivalent		
31	Electrical Systems and Fault Finding		New unit no equivalent		
32	CAD for Maintenance Engineers		New unit, no equivalent		
73	Materials Engineering with Polymers	155	Materials Engineering with Polymers	Unit 155: LO1 Unit 155: LO2 Unit 155: LO3 Unit 155: LO4	Unit 73: LO1 Unit 73: LO2 Unit 73: LO3 Unit 73: LO4

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
74	Polymer Manufacturing Processes	156	Polymer Manufacturing Processes	Unit 156: LO1 Unit 156: LO2 Unit 156: LO3 Unit 156: LO4	Unit 74: LO1 Unit 74: LO2 Unit 74: LO3 Unit 74: LO4
75	Industry 4.0		New unit, no equivalent		
76	Introduction to Professional Engineering Management		New unit no equivalent		
77	Industrial Robots		New unit, no equivalent		
78	Programmable Logic Controllers		New unit no equivalent		
79	Computer Aided Design (CAD) for Engineering		New unit, no equivalent		
80	Welding Technology	154	Welding Technologies	Unit 154: LO1 Unit 154: LO2 Unit 154: LO3 Unit 154: LO4	Unit 80: LO1 Unit 80: LO2 Unit 80: LO3 Unit 80: LO4
81	Welding Inspection	153	Welding Inspection	Unit 153: LO1 Unit 153: LO2 Unit 153: LO3 Unit 153: LO4	Unit 81: LO1 Unit 81: LO2 Unit 81: LO3 Unit 81: LO4
82	Statistical Process Control		New unit, no equivalent		

RQF HNC Units		QCF HNC units		Mapping comments	
No	RQF unit title	No	QCF unit title	QCF LOs	RQF LOs
83	Telecommunication Principles	118	Telecommunication Principles	Unit 118: LO1 Unit 118: LO2 Unit 118: LO3 Unit 118: LO4	Unit 83: LO1 Unit 83: LO1/LO2/LO3 (partial) Unit 83: LO2/LO3 (partial) Unit 83: LO4
84	Semiconductor Manufacture		New unit, no equivalent		
85	Semiconductor Production Environment		New unit, no equivalent		

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