BTEC

Pearson
Higher National in
Rail Engineering

Specification

First Teaching from January 2019
First Certification from 2020
Issue 2

Level 4
BTEC Higher National Certificate

Pearson

About Pearson

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

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

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

ISBN 978 1 446 95931 2

Summary of changes in Pearson BTEC Higher Nationals in Rail Engineering Issue 2

<table>
<tr><th>Summary of changes made between previous issue and this current issue</th><th>Page number</th></tr>
<tr><td>Unit 1
Corrected assessment criteria (LO2) – Clarified and improved grammar in P5 and M3
Amended assessment criteria (LO3)
Amended P7 to ensure holistic assessment and scaffolding principle
Deleted assessment criteria M5
Amended M4 to ensure holistic assessment and scaffolding principle
Amended D3 to clarify requirement
Amended assessment criteria (LO4)
Renumbered M6 to M5
Clarified and improved grammar of M5 and D4 to ensure holistic assessment and scaffolding principle</td><td>75-81</td></tr>
<tr><td>Unit 2
Corrected LO2 – removed the following '<s>by using appropriate computer software packages</s>'
Corrected Essential Content (LO1) – replaced term 'circular' with 'trigonometric'
Insertion into Essential Content (LO2) – inserted the line 'Charts, graphs and tables to present data'
Amended Essential Content (LO4) – Revised section on 'Integration of functions'
Amended Assessment Criteria (LO1)
inserted 'logarithmic' into P3
removed 'statistical' from D1
Amended Assessment Criteria (LO2) – Clarified P4 to ensure holistic assessment and scaffolding principle
Amended Assessment Criteria (LO3) – Corrected requirement in M3
Amended Assessment Criteria (LO4) – Replaced term 'circular' with 'trigonometric' in P8</td><td>82-87</td></tr>
</table>

Unit 3 Corrected LO1 – Replaced term '*computational*' with '*qualitative*' Amended Essential Content (LO2) – Replaced term '*objects*' with '*beams*' and inserted term '*uniformly*' Amended Essential Content (LO3) – Replaced term '*plastics*' with '*polymers*' Amended Assessment Criteria (LO1) – Corrected command verb and replaced term '*computational*' with '*qualitative*' in D1 Amended Assessment Criteria (LO2) • Clarified P3 • Amended P5 to ensure holistic assessment and scaffolding principle • Clarified and amended D2 to ensure holistic assessment and scaffolding principle Amended Assessment Criteria (LO3) • Replaced 'electrical and magnetic' with 'electromagnetic' in M3 • Clarified requirement in D3 Amended Assessment Criteria (LO4) – Clarified P8, P9, P10 and D4 to ensure holistic assessment and scaffolding principle	88-93
Unit 23 Corrected LO1 – removed term '~~*simple*~~' Corrected LO2 – removed term '~~*simple*~~' Insertion into Essential Content (LO3) – Inserted the following '*Simple semiconductor applications:* *Diodes: AC-DC rectification, light emitting diode, voltage regulation Transistors: switches and signal amplifiers.*' Amended Assessment Criteria (LO1) – Amended D1 to ensure holistic assessment and scaffolding principle Amended Assessment Criteria (LO2, LO3 and LO4) – Amended P2, M2, M3, M4, D2, D3 and D4 to ensure holistic assessment and scaffolding principle	227-233

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

Contents

1 Introduction

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

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

When developing the Pearson BTEC Level 4 Higher National Certificate in Rail 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 5, 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 Pearson BTEC Higher National Certificate in Rail Engineering is designed to reflect this increasing need for high quality professional and technical education pathways at Level 4. 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 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
- 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 Levels 4 and 5 which is aligned with the Framework for Higher Education Qualifications (FHEQ)
- support for student and tutors, including Schemes of Work and Example Assessment Briefs (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 http://www.highernationals.com

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

1.4 Qualification titles

Pearson BTEC Level 4 Higher National Certificate in Rail Engineering

Specialist pathways are included within brackets in the qualification title:

- Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Track)
- Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Power)
- Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Command and Control)
- Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Traction and Rolling Stock)
- Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Rail Systems)

1.5 Qualification codes

Regulated Qualifications Framework (RQF) Qualification Number:

- Pearson BTEC Level 4 Higher National Certificate in Rail Engineering: 603/3933/0

1.6 Awarding organisation

Pearson Education Ltd.

1.7 Key features

Pearson BTEC Higher National qualifications in Rail 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 into further study or the world of work
- a simplified structure: students undertake a substantial core of learning in the Level 4 HNC Certificate with specialist and optional units linked to their specialist area of study
- five specialist pathways at Level 4, so there is something to suit each student's preference of study and future progression plans
- refreshed content that is closely aligned with Professional Body, employer and higher education needs
- assessments that consider cognitive skills (what students know) along with affective and applied skills (respectively how they behave and what they can do)
- unit-specific grading and Pearson-set assignments
- a varied approach to assessment that supports progression to Level 5 and also allows Centres to offer assessment relevant to the local economy, thereby accommodating and enhancing different learning styles

- Quality Assurance measures – as outlined in Sections 6 and 7 of this programme specification – to ensure that all stakeholders (e.g. Professional Bodies, universities, 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 rail engineering
- a pathway into employment for apprentices in relevant rail engineering settings through completion of the HNC element of the Pearson BTEC Higher National Certificate in Rail Engineering qualification which is recognised as meeting the qualification requirements for the Rail Engineering Advanced Technician Higher Apprenticeship Standard.

Qualification frameworks

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

1.8 Collaborative development

Students completing their Pearson BTEC Higher National Certificate in Rail Engineering will be aiming to go on to employment or progress onto a Level 5 Engineering qualification. 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:

- Siemens
- DEG Signal
- Network Rail
- Babcock
- Alstom
- National College for High Speed Rail
- National Skills Academy for Rail
- PROCAT
- The Institution of Engineering and Technology
- NECOL
- York College.

1.9 Professional Body consultation and approval

The Pearson BTEC Level 4 Higher National Certificate in Rail Engineering is set at Level 4 and has been written with reference to the Engineering Council specification for Levels 3 and 5. The content and level has been written following advice from the Professional Bodies listed in *section 1.8* above and is intended to exempt holders of this qualification from the Level 4 requirements of these bodies, and articulate with the Level 5 in engineering courses.

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

Apprenticeships

The Pearson BTEC Level 4 Higher National Certificate in Rail Engineering is referenced against the Rail Engineering Advanced Technician Higher Apprenticeship Standard.

Further details of this are provided in *Section 4.5.*

2 Programme purpose and objectives

2.1 Purpose of the Pearson BTEC Higher National Certificate in Rail Engineering

The purpose of Pearson BTEC Higher National Certificate in Rail 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 National Certificate in Rail Engineering

The objectives of the Pearson BTEC Higher National Certificate in Rail 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 rail engineering profession
- to build a body of specialist knowledge, skills and techniques in order to be successful in a range of careers in rail engineering at the Associate Engineer or Operational Engineer level
- to develop the skills necessary in students to fault find and problem solve in a timely, professional manner, reflecting on their work and contributing to the development of the process and environment they operate within
- to understand the responsibilities of the rail 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 rail 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 provide opportunities for students to develop the skills, techniques and personal attributes essential for successful working lives
- to provide opportunities for students to achieve a nationally-recognised professional qualification within their chosen area of specialisation
- to offer students the chance of career progression in their chosen field, with particular emphasis on achieving management-level positions, professional recognition and beyond
- to allow flexibility of study and to meet local or specialist needs.

We aim to meet these objectives by:

- providing a thorough grounding in rail engineering principles at Level 4 that leads the student to a range of engineering progression pathways at Level 5, relating to individual professions within the 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
- to provide insight and understanding into the diversity of roles within the rail engineering sector, recognising the importance of collaboration at all levels
- to equip students with knowledge and understanding of culturally diverse organisations, cross-cultural issues, diversity and values.

Who is this qualification for?

The BTEC Higher National qualifications in Rail 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 rail engineering. In addition to the skills, knowledge and techniques that underpin the study of the sector, the Pearson Pearson BTEC Higher National Certificate in Rail Engineering gives students experience of the breadth and depth of the sector that will prepare them for employment, progression within employment or further study.

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

The Level 4 Higher National Certificate in Rail 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 Level 4 Higher National Certificate offers five pathways for students who wish to concentrate on a particular aspect of engineering:

- Track
- Power
- Command and Control
- Traction and Rolling Stock
- Rail Systems.

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 Track pathway, students take the four mandatory core units, 2 specialist units and 2 additional optional units
- For the Power pathway, students take the four mandatory core units, 3 specialist units and 1 additional optional unit
- For the Command and Control pathway, students take the four mandatory core units, 2 specialist unit and 2 additional optional units
- For the Traction and Rolling Stock pathway, students take the four mandatory core units, 2 specialist units and 2 additional optional unit
- For the Rail Systems pathway, students take the four mandatory core units, 1 specialist units and 3 additional optional unit.

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

Students 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 What could these qualifications lead to?

The Level 4 Higher National Certificate provides a solid grounding in rail engineering, which students can build on should they decide to continue their studies beyond the Certificate stage.

On successful completion of the Level 4 Higher National Certificate, students can develop their careers in the engineering sector through:

- entering employment
- continuing existing employment
- linking with the appropriate Professional Body
- committing to Continuing Professional Development (CPD)
- Progressing to the Level 5 Higher National Diploma in Engineering or equivalent Level 5 engineering course.

Pathway	Typical Job Roles after HNC
Track	Track Technician
Power	Overhead Line Engineer, Electrification Engineer
Command and Control	Signalling Technician, Telecommunications Technician
Traction and Rolling Stock	Rolling Stock Engineer
Rail Systems	Rail Systems Technician

2.5 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 in accordance with industry requirements and below are some examples of how these skills are developed in the BTEC Higher National curriculum:

- written reports
- formal presentations
- informal conversations
- use of professional, sector-specific language
- use of algebraic, logarithmic and circular functions
- use of analytical and computational methods to evaluate and solve engineering problems
- use of integral calculus to solve practical problems relating to engineering.

Some aspects of 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*). A Level 3 Maths qualification or qualification that interludes a Level 3 Maths unit/s would be advised.

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

2.6 How Higher National Certificate in Rail 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 qualifications embed throughout the programme the development of key skills, attributes and strengths required by 21st-century employers.

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

- **Cognitive and problem-solving skills**: critical thinking, approaching non-routine problems by applying expert and creative solutions, use of systems and digital technology, generating and communicating ideas creatively
- **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.

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, 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 2*.

3 Planning your programme

3.1 Delivering the Higher National qualifications in Rail Engineering

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 Rail Engineering (or related subject)
- a GCE Advanced Level profile that demonstrates strong performance in a relevant subject or adequate performance in more than one GCE subject
- 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 BTEC Higher Nationals, through Recognition of Prior Learning. (For further information please refer to *Section 8* of this document.)

English language requirements

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

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

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

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

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

Centre approval

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

Level of sector knowledge required

We do not set any requirements for tutors, but we do recommend that Centres assess the overall skills and knowledge of the teaching team, which should be relevant, up to date and at the appropriate level. For practice-based evidence assessed in the workplace, tutor-assessors must have experience in working in the rail engineering sector and hold or be working towards a recognised assessor qualification within 12 months of starting to assess evidence in the workplace.

Resources required

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

HN Global support

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

Modes of delivery

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

- full-time
- part-time
- blended learning.

Recommendations for employer engagement

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

Support from Pearson

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

Student employability

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

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

3.3 Access to study

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

Our policy regarding access to our qualifications is that:

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

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

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

3.4 Student registration and entry

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

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

3.5 Access to assessment

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

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

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

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

3.6 Administrative arrangements for internal assessment

Records

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

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

Reasonable adjustments to assessment

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

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

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

Special consideration

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

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

Appeals against assessment

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

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

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

3.7 Dealing with malpractice in assessment

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

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

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

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

Internally assessed units

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

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

Student malpractice

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

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

Tutor/centre malpractice

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

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

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

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

Sanctions and appeals

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

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

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

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

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

Your centre will be notified if any of these apply.

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

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

4 Programme structure

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

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

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 to be required for a student to achieve and demonstrate the achievement of the level of attainment necessary for the award of a qualification. TQT includes undertaking each of the activities of Guided Learning, Directed Learning and Invigilated Assessment. Each 15-credit unit approximates to a TQT of 150 hours and 60 hours of Guided Learning.

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

Examples of activities which can contribute to TQT include:

- guided Learning
- independent and unsupervised research/learning
- unsupervised compilation of a portfolio of work experience
- unsupervised e-learning
- unsupervised e-assessment
- unsupervised coursework
- watching a pre-recorded podcast or webinar
- unsupervised work-based learning.

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

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

Some examples of activities which can contribute to GL include:

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

4.2 Programme structures

The programme structures specify:

- the total credit value of the qualification
- the minimum credit to be achieved at the level of the qualification
- the core units
- the specialist units
- the optional units
- the maximum credit value in units that can be centre commissioned.

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

Unit numbering

A number of units within the Pearson BTEC Level 4 Higher National Certificate in Rail Engineering qualification also appear in the Pearson BTEC Higher Nationals in Engineering, Business, Computing and Construction qualifications.

While the content and unit codes of these units are identical, the unit numbers are different.

UNIT TITLE	UNIT CODE	UNIT NUMBER	
		HNC Rail Engineering	**HNC Engineering**
Engineering Design	K/615/1475	1	1
Engineering Maths	M/615/1476	2	2
Engineering Science	T/615/1477	3	3
Managing a Professional Engineering Project	A/615/1478	4	4
Renewable Energy	F/615/1479	14	5
Machining and Processing of Engineering Materials	A/615/1481	15	7
Mechanical Principles	F/615/1482	16	8
Materials, Properties and Testing	J/615/1483	17	9
Engineering Management	Y/615/1486	18	12
Electro, Pneumatic and Hydraulic Systems	L/615/1498	19	29
Automation, Robotics and Programmable Logic Controllers (PLCs)	K/615/1489	20	15
Instrumentation and Control Systems	D/615/1490	21	16

Quality and Process Improvement	H/615/1491	22	17
Electrical and Electronic Principles	M/615/1493	23	19
Digital Principles	T/615/1494	24	20
Electronic Circuits and Devices	F/615/1496	25	22
		HNC Rail Engineering	**HNC Business**
Management and Operations	D/508/0488	26	4
		HNC Rail Engineering	**HNC Computing**
Programming	D/615/1618	27	1
Networking	H/615/1619	28	2
Strategic Information Systems	A/615/1626	29	7
Computer Systems Architecture	J/615/1628	30	8
		HNC Rail Engineering	**HNC Construction**
Construction Technology	Y/615/1388	31	2
Surveying, Measuring & Setting Out	H/615/1393	32	7

Pearson BTEC Level 4 Higher National Certificate in Rail 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:

Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Track) (120 credits)		**Unit credit**	**Level**
Core unit *Mandatory*	**1 Engineering Design**	15	4
Core unit *Mandatory*	**2 Engineering Maths**	15	4
Core unit *Mandatory*	**3 Engineering Science**	15	4
Core unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist *Mandatory*	**5 Railway Operations**	15	4
Specialist *Mandatory*	**6 Track Design**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group A (see below)**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group A (see below)**	15	4

Higher National Certificate Optional Units		Unit credit	Level
Optional Unit Bank Level 4 Group A: Track			
Optional	**7 Command and Control Systems**	15	4
Optional	**15 Machining and Processing of Engineering Materials**	15	4
Optional	**17 Materials, Properties and Testing**	15	4
Optional	**19 Electro, Pneumatic and Hydraulic Systems**	15	4
Optional	**31 Construction Technology**	15	4
Optional	**32 Surveying, Measuring & Setting Out**	15	4

Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Power) (120 credits)		Unit credit	Level
Core unit *Mandatory*	**1 Engineering Design**	15	4
Core unit *Mandatory*	**2 Engineering Maths**	15	4
Core unit *Mandatory*	**3 Engineering Science**	15	4
Core unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist *Mandatory*	**5 Railway Operations**	15	4
Specialist *Mandatory*	**9 Principles of Electrification**	15	4
Specialist *Mandatory*	**12 Traction and Rolling Stock Systems**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group B (see below)**	15	4

Higher National Certificate Optional Units		Unit credit	Level
Optional Unit Bank Level 4 Group B: Power			
Optional	**6 Track Design**	15	4
Optional	**7 Command and Control Systems**	15	4
Optional	**8 Principles of Overhead Power**	15	4
Optional	**14 Renewable Energy**	15	4
Optional	**15 Machining and Processing of Engineering Materials**	15	4
Optional	**16 Mechanical Principles**	15	4
Optional	**19 Electro, Pneumatic and Hydraulic Systems**	15	4
Optional	**20 Automation, Robotics and Programmable Logic Controllers (PLCs)**	15	4
Optional	**21 Instrumentation and Control Systems**	15	4
Optional	**23 Electrical and Electronic Principles**	15	4
Optional	**24 Digital Principles**	15	4
Optional	**25 Electronic Circuits and Devices**	15	4
Optional	**31 Construction Technology**	15	4
Optional	**32 Surveying, Measuring & Setting Out**	15	4

Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Command and Control) (120 credits)		Unit credit	Level
Core unit *Mandatory*	**1 Engineering Design**	15	4
Core unit *Mandatory*	**2 Engineering Maths**	15	4
Core unit *Mandatory*	**3 Engineering Science**	15	4
Core unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist *Mandatory*	**5 Railway Operations**	15	4
Specialist *Mandatory*	**7 Command and Control Systems**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group C (see below)**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group C (see below)**	15	4

Higher National Certificate Optional Units		Unit credit	Level
Optional Unit Bank Level 4 Group C: Command and Control			
Optional	**6 Track Design**	15	4
Optional	**10 Introduction to Signalling Systems**	15	4
Optional	**11 Railway Telecommunications**	15	4
Optional	**16 Mechanical Principles**	15	4
Optional	**20 Automation, Robotics and Programmable Logic Controllers (PLCs)**	15	4
Optional	**21 Instrumentation and Control Systems**	15	4
Optional	**23 Electrical and Electronic Principles**	15	4
Optional	**24 Digital Principles**	15	4
Optional	**25 Electronic Circuits and Devices**	15	4
Optional	**27 Programming**	15	4
Optional	**28 Networking**	15	4
Optional	**29 Strategic Information Systems**	15	4

Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Traction and Rolling Stock) (120 credits)		Unit credit	Level
Core unit *Mandatory*	**1 Engineering Design**	15	4
Core unit *Mandatory*	**2 Engineering Maths**	15	4
Core unit *Mandatory*	**3 Engineering Science**	15	4
Core unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist *Mandatory*	**5 Railway Operations**	15	4
Specialist *Mandatory*	**12 Traction and Rolling Stock Systems**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group D (see below)**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group D (see below)**	15	4

Higher National Certificate Optional Units		Unit credit	Level
Optional Unit Bank Level 4 Group D: Traction and Rolling Stock			
Optional	**6 Track Design**	15	4
Optional	**7 Command and Control Systems**	15	4
Optional	**11 Railway Telecommunications**	15	4
Optional	**13 Passenger Safety and Security**	15	4
Optional	**16 Mechanical Principles**	15	4
Optional	**17 Materials, Properties and Testing**	15	4
Optional	**19 Electro, Pneumatic and Hydraulic Systems**	15	4
Optional	**20 Automation, Robotics and Programmable Logic Controllers (PLCs)**	15	4
Optional	**21 Instrumentation and Control Systems**	15	4
Optional	**23 Electrical and Electronic Principles**	15	4
Optional	**24 Digital Principles**	15	4
Optional	**25 Electronic Circuits and Devices**	15	4
Optional	**29 Strategic Information Systems**	15	4
Optional	**30 Computer Systems Architecture**	15	4

Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Rail Systems) (120 credits)		Unit credit	Level
Core unit *Mandatory*	**1 Engineering Design**	15	4
Core unit *Mandatory*	**2 Engineering Maths**	15	4
Core unit *Mandatory*	**3 Engineering Science**	15	4
Core unit *Mandatory*	**4 Managing a Professional Engineering Project (Pearson-set)**	15	4
Specialist *Mandatory*	**5 Railway Operations**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group E (see below)**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group E (see below)**	15	4
Optional unit	**Plus one optional unit from Optional Unit Bank Level 4 Group G (see below)**	15	4

Higher National Certificate Optional Units		Unit credit	Level
Optional Unit Bank Level 4 Group E: Rail Systems			
Optional	**6 Track Design**	15	4
Optional	**7 Command and Control Systems**	15	4
Optional	**10 Introduction to Signalling Systems**	15	4
Optional	**14 Renewable Energy**	15	4
Optional	**23 Electrical and Electronic Principles**	15	4

Higher National Certificate Optional Units		Unit credit	Level
Optional Unit Bank Group G: Rail Systems			
Optional	**18 Engineering Management**	15	4
Optional	**22 Quality and Process Improvement**	15	4
Optional	**26 Management and Operations**	15	4

Meeting local needs and centre-devised units

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

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

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

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

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

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

Pathway	Import Level 4
Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Track)	30 credits
Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Power)	15 credits
Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Command and Control)	30 credits
Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Traction and Rolling Stock)	30 credits
Pearson BTEC Level 4 Higher National Certificate in Rail Engineering (Rail Systems)	30 credits

4.3 Pearson-set Assignments

There are Pearson-set assignments, as part of the 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, students will select a Topic to further define their approach to the Theme and assignment.

For example, from the Higher Nationals in Business:

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

Level 4 Topics:

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

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

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

4.4 Annotated unit descriptor

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

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

There are three unit types: core units (which students have to complete to achieve either the Level 4 Certificate specialist units (which students have to complete when studying one of the specialist pathways) and optional units, which can be chosen.

All Higher National Certificate units are at Level 4.

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

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

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

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

PEARSON ALWAYS LEARNING

Unit 16: Automation, Robotics and Programmable Logic Controllers

Unit type	Optional
Unit level	4
Credit value	15
TQT	150

Introduction

The word automation was not used until the 1940s and it originated in the automotive manufacturin sector as a method designed to reduce labour costs and improve the quality, accuracy and precisio 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 b 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 o programming languages; types of robots and cell safety features.

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

Learning Outcomes

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

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

LWAYS LEARNING

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

Essential Content

LO1 Analyse the design and operational characteristics of a PLC system.

System operational characteristics
Modular, unitary and rack mounted systems.
Characteristics, including; speed, memory, scan time, voltage and current limits.
Input and output devices (digital, analogue).
Interface requirements.
Communication standards (RS-232, RS-422, RS-485, Ethernet).
Internal architecture.
Different types of programming languages (IEC 61131-3).

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

Programming language
Signal types.
Number systems (binary, octal, hexadecimal).
Allocation lists of inputs and outputs.
Communication techniques.
Network methods.
Logic functions (AND, OR, XOR).
Associated elements (timers, counters, latches).

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

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

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

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

Safety
Cell safety features
Operating envelope
Operational modes
User interfaces

ALWAYS LEARNING

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

PEARSON ALWAYS LEARNING

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse the design and operational characteristics of a PLC system.		D1 Analyse the internal architecture of a typical PLC to determine its operational applications.
P1 Describe the key differences of PLC construction styles and their typical applications. P2 Determine the types of PLC input and output devices available. P3 Describe the different types of communication links used with PLC's.	M1 Explain the different types of PLC programming languages available.	
LO2 Design a simple PLC program by considering PLC information, programming and communication techniques.		D2 Design and produce all elements of a PLC program for a given industrial task.
P4 Describe the design elements that have to be considered in the preparation of a PLC programme program P5 Explain how communication connections are correctly used with the PLC.	M2 Examine the methods used for testing and debugging the hardware and software.	
LO3 Investigate the key elements of industrial robots and be able to program them with straightforward commands to perform a given task.		D3 Design and produce a robot program for a given industrial task.
P6 Describe the types of industrial robots and their uses in industry. P7 Describe the types of robot end effectors available and their applications.	M3 Explain a given industrial robotic system and make recommendations for improvement.	
LO4 Investigate the design and safe operation of a robot within an industrial application.		D4 Design a safe working plan for an industrial robotic cell in a given production process to include a full risk assessment.
P8 Describe the safety systems used within an industrial robotic cell.	M4 Explain the systems in place to ensure safe operation of a given industrial robotic cell.	

ALWAYS LEARNING

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

PEARSON ALWAYS LEARNING

Recommended Resources

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

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

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

Website based resources – referencing:

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

1 A link to the main page of the website

2 The title of the site

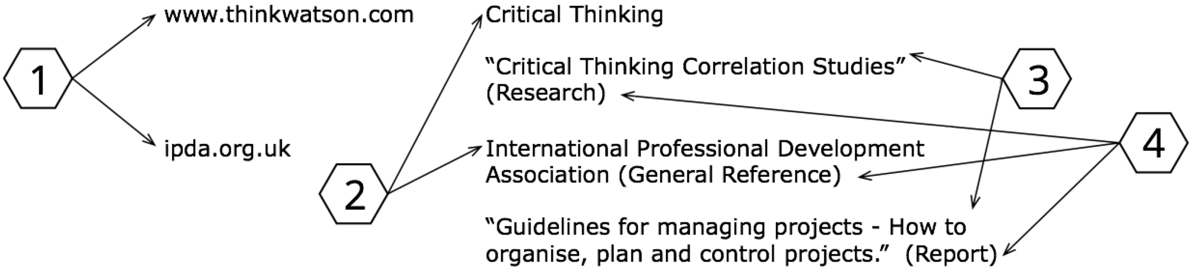
3 The name of the section or element of the website where the resource can be found

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

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

Some examples from computing units have been shown below:

Websites



4.5 Apprenticeships

The Pearson BTEC Level 4 Higher National Certificate in Rail Engineering is referenced against the Higher Apprenticeship Standard for the Rail Engineering Advanced Technician, published by the Institute for Apprenticeships, and can be taken as part of the mandatory on-programme element of the standard. This standard was developed by the Rail Engineering Trailblazer group, which is made up of employers from Rail Engineering and facilitated by National Skills Academy for Rail.

Mapping to the Apprenticeship Standards can be found in *Appendix 1* of this specification.

5 Teaching and learning

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

Centres are encouraged to develop programmes that have a distinctive focus on entry into work; delivering a curriculum that embeds employability, has a strong commitment to ethics and diversity, and introduces students to contemporary as well as seminal research. All teaching and learning should reflect the expectations of employers and society and be informed and guided by external benchmarks such as professional and statutory bodies. In so doing students completing a Pearson BTEC Level 4 Higher National Certificate in Rail 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 counsel student opinions on a range of teaching and learning matters, which would be used to inform and enhance future practice within a programme of study and within a centre.

5.1 Delivering quality and depth

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

In addition to delivering a quality learning experience, Centres must also encourage students to have a deeper understanding of the subject where they are able to go beyond the fundamentals of explaining and describing. Students are expected to show they can analyse data and information, make sense of this and then reach evaluative judgements.

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

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

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

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

An induction programme should consist of the following:

- course programme overview
- preparing for lessons
- effective engagement in lectures and seminars
- making the most of their tutor
- assignment requirements
- referencing and plagiarism
- centre policies
- academic study skills.

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

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

5.2 Engaging with employers

Just as the student voice is important, so too is the employer's. Employers play a significant role in the design and development of all regulated qualifications, including the Pearson BTEC Level 4 Higher National Certificate in Rail Engineering. This input should extend into the learning experience, where engagement with employers will add value to students, particularly in transferring theory into practice. Work placement is a mandatory and essential element of the students' programme and development, and is integrated throughout the qualification. Centres are encouraged to actively engage employers in the delivery and assessment of aspects of the programme as relevant.

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

- work placement (mandatory)
- field trips to local rail engineering settings
- inviting local rail engineering employers, service users and deliverers to present guest lectures
- using employers to judge the quality of assessed presentations and/or products
- (For the more entrepreneurial) establishing a panel of experts to whom students can present their research and recommendations for improvement.

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

5.3 Engaging with students

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

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

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

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

5.4 Planning and structuring a programme

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

It is important for a programme structure to be effectively planned, taking into account the nature of the student cohort, the primary mode of delivery (face-to-face or distance learning) and the level of study. It is also advisable to consider the student voice (whether that voice is heard through end of programme feedback, or through 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. However, this does not mean that units can, or should, be delivered in any order.

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, *Unit 1: Engineering Design*, *Unit 2: Engineering Math* and *Unit 3: Engineering Science* could be the first three units that Higher National Certificate students study.

5.4.2 Condensed or expanded delivery

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

Condensed version

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

Expanded version

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

Mixed version:

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

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

The advantages of the expanded version include providing a longer timescale for students to absorb new knowledge and therefore, potentially, improve success, and giving tutors an opportunity to coach and support less able students over a longer period of time.

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

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

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

5.4.3 Drawing on a wide range of delivery techniques

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

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

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

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

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

5.4.4 Assessment considerations

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

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

5.4.5 Formative assessment

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

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

5.4.6 Summative assessment

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

5.4.7 Assessment feedback

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

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

5.4.8 Designing valid and reliable assessments

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

Use of language

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

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

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

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

Consistency

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

Employing a range of assessment tools

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

Some of the assessment tools that could be used are:

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

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

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

6 Assessment

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

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

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

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

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

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

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

Example Assessment Briefs

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

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

6.1 Principles of internal assessment

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

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

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

Assessment through assignments

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

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

Assessment decisions through applying unit-based criteria

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

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

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

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

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

The assessment team

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

- **The Programme Leader** has overall responsibility for the programme, its assessment and internal verification to meet our requirements, record keeping and liaison with the 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.
- Your EE will sample student work across assessors. Your EE will also want to see evidence of internal verification of assignments and accessment decisions.

Effective organisation

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

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

Student preparation

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

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

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

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

6.2 Setting effective assignments

Setting the number and structure of assignments

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

Pearson provide for each unit to support you in developing and designing your own assessments, if you wish to do so you can find these materials with the specification on our website.

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

- the number of assignments for a unit must not exceed the number of learning outcomes shown in the unit descriptor. However, you may choose to combine assignments, e.g. to create a single assignment for the whole unit.
- you may also choose to combine all or parts of different units into single assignments, provided that all units and all their associated learning aims are fully addressed in the programme overall. If you choose to take this approach you need to make sure that students are fully prepared, so that they can provide all the required evidence for assessment, and that you are able to track achievement in assessment records.

- a learning outcome must always be assessed as a whole and must not be split into two or more elements.
- the assignment must be targeted to the learning outcomes but the learning outcomes and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.

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

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

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

Providing an assignment brief

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

An assignment brief should have:

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

Forms of evidence

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

The Example Assessment Briefs give you information on what would be suitable forms of evidence to give students the opportunity to apply a range of employability or transferable skills.

Centres may choose to use different suitable forms of evidence to those proposed. Overall, students should be assessed using varied forms of evidence.

These are some of the main types of assessment:

- written reports
- time constrained assessments
- creation of design documents
- projects
- production of an artefact
- solutions to engineering problems through discourse and/or calculation
- academic posters, displays, leaflets
- electronic (or similar) presentations
- recordings of interviews/role plays
- working logbooks, reflective journals
- presentations with assessor questioning.

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

The form(s) of evidence selected must:

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

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

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

6.3 Making valid assessment decisions

Authenticity of student work

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

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

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

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

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

Making assessment decisions using criteria

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

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

- the explanation of key terms in *Appendix 3* of this document
- examples of verified assessed work
- Your Programme Leader and assessment team's collective experience.

Dealing with late completion of assignments

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

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

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

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

Issuing assessment decisions and feedback

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

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

Resubmission opportunity

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

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

Repeat units

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

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

Assessment Boards

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

- the grades achieved by students on the individual units
- extenuating circumstances
- cases of cheating and plagiarism
- progression of students on to the next stage of the programme
- the awards to be made to students
- referrals and deferrals.

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

Where a centre does not currently have such a process then the 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 though internal verification that covers all assignments, assessors and a range of students
- how to manage the assessment and verification of students' work so that they can be given formal decisions promptly
- how resubmission opportunities can be scheduled.

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

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

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

6.5 Calculation of the final qualification grade

Conditions for the award of the HNC

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

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

Compensation Provisions for the HNC

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

Calculation of the overall qualification grade

The calculation of the overall qualification grade is based on the student's performance in all units. Students are awarded a Pass, Merit or Distinction qualification grade using the points gained through all 120 credits, based on unit achievement.

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).

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

Points per credit

Pass: 4

Merit: 6

Distinction: 8

Point boundaries

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

Modelled Student Outcomes

Level 4 Higher National Certificate

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

7 Quality Assurance

Pearson's Quality Assurance system for all Pearson BTEC Higher National Certificate programmes is benchmarked to Level 4 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 QAA 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 Certificate programmes benchmarked to Level 4 of the 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. This is intended to exemplify the processes required for effective assessment and provide examples of effective standards. Approved Centres must use the materials and services to ensure that all staff delivering BTEC qualifications keep up to date with the guidance on assessment
- an approved centre must follow agreed protocols for standardisation of assessors and verifiers, for the planning, monitoring and recording of assessment processes, and for dealing with special circumstances, appeals and malpractice.

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

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

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

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

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

8 Recognition of Prior Learning (RPL) 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 Rail Engineering Units

Unit 1: Engineering Design

Unit code	**K/615/1475**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

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

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

Among the topics included in this unit are: Gantt charts and critical path analysis, stakeholder requirements, market analysis, design process management, modelling and prototyping, manufacturability, reliability life cycle, safety and risk, management, calculations, drawings and concepts and ergonomics.

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

Learning Outcomes

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

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

Essential Content

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

Planning techniques used to prepare a design specification:

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

Definition of design constraints, function, specification, milestones

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

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

Design process:

Process development, steps to consider from start to finish

The cycle from design to manufacture

Three- and five-stage design process

Vocabulary used in engineering design

Stage of the design process which includes:

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

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

Customer/stakeholder requirements:

Converting customer request to a list of objectives and constraints

Interpretation of design requirements

Market analysis of existing products and competitors

Aspects of innovation and performance management in decision-making

LO2 **Formulate possible technical solutions to address the student-prepared design specification**

Conceptual design and evaluating possible solutions:

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

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

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

Managing the design process:

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

Working to specifications and standards, including:

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

Design for testing, including:

Material selection to suit selected processes and technologies

Consideration of manufacturability, reliability, life cycle and environmental issues

The importance of safety, risk management and ergonomics

Conceptual design and effective tools:

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

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

Communication and post-presentation review:

Selection of presentation tools

Analysis of presentation feedback

Strategies for improvement based on feedback

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Plan a design solution and prepare an engineering design specification in response to a stakeholder’s design brief and requirements</td><td rowspan="2">D1 Compare and contrast the completed design specification against the relevant industry standard specification</td></tr>
<tr><td>P1 Produce a design specification from a given design brief

P2 Explain the influence of the stakeholder’s design brief and requirements in the preparation of the design specification

P3 Produce a design project schedule with a graphical illustration of the planned activities</td><td>M1 Evaluate potential planning techniques, presenting a case for the method chosen

M2 Demonstrate critical path analysis techniques in design project scheduling/planning and explain its use</td></tr>
<tr><td colspan="2">LO2 Formulate possible technical solutions to address the student-prepared design specification</td><td rowspan="2">D2 Evaluate potential technical solutions, presenting a case for the final choice of solution</td></tr>
<tr><td>P4 Explore industry standard evaluation and analytical tools in formulating possible technical solutions

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

Pass	Merit	Distinction
LO3 Prepare an industry-standard engineering technical design report		**D3** Evaluate the effectiveness of the industry standard engineering technical design report for producing a fully compliant finished product
P6 Prepare an industry-standard engineering technical design report **P7** Explain the role of design specifications and standards in the technical design report	**M4** Assess any compliance, safety and risk management issues specific to the technical design report	
LO4 Present to an audience a design solution based on the design report and evaluate the solution/presentation		**D4** Justify potential improvements to the design solution and/or presentation based on reflection and/or feedback
P8 Present the recommended design solution to the identified audience **P9** Explain possible communication strategies and presentation methods that could be used to inform the stakeholders of the recommended solution	**M5** Reflect on the effectiveness of the chosen communication strategy in presenting the design solution	

Recommended Resources

Textbooks

DUL, J. and WEERDMEESTER, B. (2008) *Ergonomics for beginners*. 3rd Ed. Boca Raton: CRC Press.

DYM, C.L., LITTLE, P. and ORWIN, E. (2014) *Engineering Design: a Project Based Introduction*. 4th Ed. Wiley.

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

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

Websites

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

Unit 2: Engineering Maths

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

Introduction

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

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

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

Learning Outcomes

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

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

Essential Content

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

Mathematical concepts:

Dimensional analysis

Arithmetic and geometric progressions

Functions:

Exponential, logarithmic, trigonometric and hyperbolic functions

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

Summary of data:

Mean and standard deviation of grouped data

Pearson's correlation coefficient

Linear regression

Charts, graphs and tables to present data

Probability theory:

Binomial and normal distribution

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

Sinusoidal waves:

Sine waves and their applications

Trigonometric and hyperbolic identities

Vector functions:

Vector notation and properties

Representing quantities in vector form

Vectors in three dimensions

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

Differential calculus:

Definitions and concepts

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

Differentiation of functions

Differentiation of functions including:

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

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

Integral calculus:

Definite and indefinite integration

Integrating to determine area

Integration of functions including:

- common/standard functions
- using substitution
- by parts

Exponential growth and decay

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

Engineering problems involving calculus:

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

Learning Outcomes and Assessment Criteria

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

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

Recommended Resources

Textbooks

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

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

Websites

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

Unit 3: Engineering Science

Unit code T/615/1477

Unit type Core

Unit level 4

Credit value 15

Introduction

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

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

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

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

Learning Outcomes

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

1. Examine scientific data using both quantitative and qualitative methods.
2. Determine parameters within mechanical engineering systems.
3. Explore the characteristics and properties of engineering materials.
4. Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties.

Essential Content

LO1 **Examine scientific data using both quantitative and qualitative methods**

International system of units:

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

SI derived units with special names and symbols

SI prefixes and their representation with engineering notation

Interpreting data:

Investigation using the scientific method to gather appropriate data

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

Summarising quantitative and qualitative data with appropriate graphical representations

Using presentation software to present data to an audience

LO2 **Determine parameters within mechanical engineering systems**

Static and dynamic forces:

Representing loaded components with space and free body diagrams

Calculating support reactions of beams subjected to concentrated and distributed loads

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

Fluid mechanics and thermodynamics:

Archimedes’ principle and hydrostatics

Continuity of volume and mass flow for an incompressible fluid

Effects of sensible/latent heat of fluid

Heat transfer due to temperature change and the thermodynamic process equations

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

Material properties:

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

Mechanical and electromagnetic properties of materials

Material failure:

Destructive and non-destructive testing of materials

The effects of gradual and impact loading on a material.

Degradation of materials and hysteresis

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

D.C. circuit theory:

Voltage, current and resistance in D.C. networks

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

A.C. circuit theory:

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

RLC circuits

Magnetism:

Characteristics of magnetic fields and electromagnetic force

The principles and applications of electromagnetic induction

Learning Outcomes and Assessment Criteria

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

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

P4 Use Archimedes’ principle in contextual engineering applications

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

Pass	Merit	Distinction
LO3 Explore the characteristics and properties of engineering materials		**D3** Compare and contrast theoretical material properties of metals and non-metals with practical test data
P6 Describe the structural properties of metals and non-metals with reference to their material properties **P7** Explain the types of degradation found in metals and non-metals	**M3** Review elastic and electromagnetic hysteresis in different materials	
LO4 Analyse applications of A.C./D.C. circuit theorems, electromagnetic principles and properties		**D4** Evaluate different techniques used to solve problems on a combined series-parallel RLC circuit using A.C. theory.
P8 Calculate currents and voltages in D.C. circuits using circuit theorems **P9** Describe how complex waveforms are produced from combining two or more sinusoidal waveforms. **P10** Solve problems on series RLC circuits with A.C. theory.	**M4** Explain the principles and applications of electromagnetic induction	

Recommended Resources

Textbooks

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

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

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

Journals

International Journal of Engineering Science.

International Journal of Engineering Science and Innovative Technology.

Websites

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

Links

This unit links to the following related units:

Unit 17: Materials, Properties and Testing

Unit 4: Managing a Professional Engineering Project

Unit code	**A/615/1478**
Unit type	**Core**
Unit level	**4**
Credit value	**15**

Introduction

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

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

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

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

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

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

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

Learning Outcomes

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

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

Essential Content

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

Examples of realistic engineering based problems:

Crucial considerations for the project

How to identify the nature of the problem through vigorous research

Feasibility study to identify constraints and produce an outline specification

Develop an outline project brief and design specification:

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

Ethical frameworks:

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

The National Society for Professional Engineers' Code of Ethics

Regulatory bodies:

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

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

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

Chartered Engineer, Incorporated Engineer and Engineering Technician

International regulatory regimes and agreements associated with professional engineering:

European Federation of International Engineering Institutions.

European Engineer (Eur Eng)

European Network for Accreditation of Engineering Education

European Society for Engineering Education

Washington Accord

Dublin Accord

Sydney Accord

International Engineers Alliance

Asia Pacific Economic Cooperation (APEC) Engineers Agreement

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

Project execution phase:

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

Work plan and time management, using Gantt chart or similar.

Tracking costs and timescales

Maintaining a project diary to monitor progress against milestones and timescales

Engineering professional behaviour sources:

Professional responsibility for health and safety (UK-SPEC)

Professional standards of behaviour (UK-SPEC)

Ethical frameworks:

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

The National Society for Professional Engineers' Code of Ethics

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

Convincing arguments:

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

Critical analysis and evaluation techniques:

Most appropriate evaluation techniques to achieve a potential solution

Secondary and primary data should be critiqued and considered with an objective mindset

Objectivity results in more robust evaluations where an analysis justifies a judgement

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

Presentation considerations:

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

Presentation specifics. Who to invite: project supervisors, fellow students and employers. Time allocation, structure of presentation

Reflection on project outcomes and audience reactions

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

Reflection for learning and practice:

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

The cycle of reflection:

To include reflection in action and reflection on action

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

The importance of Continuing Professional Development (CPD) in refining on-going professional practice

Reflective writing:

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

Learning Outcomes and Assessment Criteria

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

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

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

Recommended Resources

Textbooks

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

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

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

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 18: Engineering Management

Unit 5: Railway Operations

Unit code	**J/617/3662**
Unit level	**4**
Credit value	**15**

Introduction

Railway Operations is responsible for managing the operations and maintenance of rail systems, subsystems, assets and services to ensure that they function in an effective, safe and synchronised way. Rail Engineers and technicians are critical to operations and are required to understand how these elements function, interface and interact to prevent failures and optimise overall rail operations. It involves systems and assets such as signalling, electrification, telecommunications, traction & rolling stock, stations, command & control, tracks and many others.

This unit focuses on how the railway works as a system and the role that advanced rail technicians have within it. Identifying critical functions and interfaces across the railway system and how to manage their operation and maintenance. Discussing the importance of 3rd party and internal business requirements and operational interfaces; the need for and understanding of client confidentiality and compliance with corporate policies including ethics, equality and diversity and sustainability; and how the railway works commercially including contractual principles and financial systems, forecasts and budgets, and performance implications and performance management techniques.

The unit explores how the railway is evolving. Taking into consideration the awareness and understanding of new technological developments across the Railway and how these will impact its future operation.

Students who have completed this unit as part of their HNC studies will be well placed to apply for employment as Advanced Rail Technicians or other similar roles within the railway industry.

Learning Outcomes

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

1. Explain how the railway works as a system
2. Explore the role that rail technicians have in railway operations
3. Explain the commercial operations of a railway
4. Explore the ways in which the railway is evolving

Essential Content

LO1 **Explain how the railway works as a system**

The railway system:

The various systems, subsystems and assets that form a railway system

The principle function and significance of each system and asset to rail operation

How the systems and assets interact together to operate a railway

The interfaces across a railway system:

The different interfaces between the systems of a railway

The requirements, conditions and tolerances of the different types of interfaces

The criticality levels of the system interfaces and impacts of failures on the operation of a railway

The monitoring and response systems developed to reduce the risk of system and interface failures

LO2 **Explore the role that rail technicians have in railway operations**

Management of the operations and maintenance of a railway system:

Understand the relationship between operations management and the maintenance system and how they impact the performance of the railway system

Identify and distinguish between systems and assets that function within solely operations management, solely maintenance or a combination of both responsibilities

Importance of adhering to maintenance schedules and using optimisation activities to increase railway operation reliability and reduce the rate of system and asset failures

The analytical approach to monitoring the performance of all railway systems, understanding the major risk factors, real time detection of unexpected changes and problem-solving approach to issues.

System and asset maintenance activities such as engineering walkdowns, inspections & testing, categorising findings & defects and reporting issues.

Conduct and supervise railway system repairs

Comply with required Quality Assurance and Health & Safety regulations and procedures when performing operations and maintenance activities

Keeping operations and maintenance records updated.

Understand the impacts business requirements, security, client confidentiality and compliance with corporate policies have on railway operations:

Differentiate between the conditions, requirements and approach taken when facing 3rd party businesses as opposed to internal businesses

Adhere to privacy, data protection, security and corporate policies and regulations

LO3 **Explain the commercial operations of a railway**

Focus of commercial operations:

Markets and customers

Freight services

Commercial railway departments:

Financial systems, forecasting and budgeting

Planning and timetabling

Contracts and contractual principles

Sales and marketing

Performance Management:

Performance implications

Performance management techniques

LO4 **Explore the ways in which the railway is evolving**

Current concerns that the future railway systems will have to address:

Growing passenger and freight demands

Costs of construction, maintenance and operation

Energy efficiency, carbon footprint and environmental protection

Rising expectations and adaptation of customers

Current and future technological developments in the railway:

High-speed and hyper-speed rail

Ergonomic station design

Big data and real time signalling

Passenger entertainment and interactive services

High speed internet using 5G

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain how the railway works as a system		**D1** Illustrate through the use of examples how the railway system performance is impacted by human behaviour and is a key factor of unreliability
P1 Describe the various system and assets used on the railway, their interfaces and functions **P2** Discuss how the various assets within a railway work together as a system	**M1** Investigate the impacts and complications that different system interfaces can have on the overall railway performance	
LO2 Explore the role that rail technicians have in railway operations		**D2** Evaluate how Quality Assurance regulations and conditions can differ between work carried out by 3rd party businesses and internal businesses
P3 Illustrate how the operations management and maintenance systems relate to each other regarding the overall operation of a railway. **P4** Explore the role of rail technicians in the maintenance and optimization of railway operations **P5** Examine the impacts business requirements, security, client confidentiality and compliance with corporate policies have on railway operations	**M2** Assess the impact that poor adherence to the maintenance schedule can have on the overall reliability and performance of railway operations.	
LO3 Explain the commercial operations of a railway		**D3** Justify why it is important to monitor and manage the commercial performance of the railway and what the implications may be if it is not managed well
P6 Describe the focus and scope of railway commercial operations **P7** Discuss the importance of planning and monitoring of the commercial performance of the railway	**M3** Examine the functions of the various commercial railway departments and the importance of monitoring and managing commercial performance	

Pass	Merit	Distinction
LO4 Explore the ways in which the railway is evolving.		**D4** Justify how higher passenger numbers and customer expectations drive the adoption of new technological developments in railways
P8 Identify the current concerns that future railway systems will have to address **P9** Discuss what technological developments are being made to address current social and economical rail operations concerns and how they are evolving	**M4** Analyse the major technological advancements and socio-economic factors that likely effect the evolution of the railway in the future	

Recommended Resources

Textbooks

PYRGIDIS, C.N. (2018). *Railway Transportation Systems: Design, Construction and Operation*. London: CRC PRESS.

Websites

uic.org	International Union of Railways (General reference)
www.theiet.org	The IET Railway Network Railway (General Reference)
www.railway-technical.com	Railway Technical (General Reference)
www.imeche.org	IMechE Railway Railway (General Reference)

Links

This unit links to the following related units:

Unit 6: Track Design

Unit 7: Command and Control

Unit 9: Principles of Electrification

Unit 10: Introduction to Signalling Systems

Unit 11: Railway Telecommunications

Unit 12: Traction and Rolling Stock

Unit 13: Passenger Safety and Security

Unit 18: Engineering Management

Unit 21: Quality and Process Improvement

Unit 25: Management and Operations

Unit 6: Track Design

Unit code L/617/3663

Unit level 4

Credit value 15

Introduction

The safe and timely transit of passengers on railways depends to a great extent on the condition and performance of the railway track infrastructure. The design geometry of the track also determines the train capacity and speed of trains. Track technicians ensure that the tracks and surrounding environment are monitored, maintained and kept safe and secure to ensure the undisturbed operation of the railway. Graduates who have completed this unit as part of their HNC studies will be very well placed to apply for employment as Track Advanced Technicians or other similar roles within the railway industry.

This unit focuses on the knowledge and skills that Track Advanced Technicians must have and this includes different techniques and methods used to construct, install, maintain and renew tracks and associated assets, and ensure that railway asset, equipment, process and systems failures are prevented and avoided. Furthermore, it provides in-depth understanding and broad experience of track geometry and its impact on train wheels; the requirements, methods and techniques for the installation and maintenance of the track and track foundation; and the impact of the environment on the railway. The physical and systems interfaces between the track and other aspects of the railway and the operating requirements, implications and constraints of these are also covered.

Learning Outcomes

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

1. Explain railway infrastructure construction, rail technologies and environmental constraints
2. Explain the various techniques used in track maintenance, renewal and replacement
3. Undertake railway track condition and performance evaluation and troubleshooting
4. Demonstrate responsibility in the construction, reinstatement and enhancement of the railway track and its environment.

Essential Content

LO1 **Explain railway infrastructure construction, rail technologies and environmental constraints**

The railway infrastructure construction:

Railway track infrastructure construction preparatory activities

Earthwork activities undertaken in association with railway track infrastructure

Construction and material specifications used in railway track infrastructure.

Rail technologies:

Surveying techniques at compliance level

Materials in the rail environment

Mechanical systems in the rail environment

Electrical and electronic systems in the rail environment

The interface between the various railway systems.

The rail environment:

The need to include health and safety in all work practices and procedures within the rail environment

Types of drainage and drainage solutions used in the rail environment

Maintenance requirements for draining and drainage solutions

The need and process for securing the railway during work

Types and uses of different fencing materials.

LO2 **Explain the various techniques used in track maintenance, renewal and replacement**

Track maintenance processes and activities:

Techniques used to identify and correct defects

Track maintenance activities

Identifying defects and discrepancies in components prior to use

Range of monitoring equipment available

Methods and techniques for temporary and permanent component removal

Track renewal and replacement:

Track renewal versus track maintenance activities

Planning track renewal activities

Equipment used in track renewal activities

Methods and techniques for component and asset replacement

Undertaking track renewal activities.

LO3 **Undertake railway track condition and performance evaluation and troubleshooting**

Analyse and evaluate the performance and condition of:

Railway track infrastructure, including rails, points and junction

Conductor rail and cable systems

Rail environment.

Diagnosis and troubleshooting:

Use detailed data analysis

Perform detailed inspection of the track and its environment

Use appropriate types of tests to diagnose and confirm faults

Use appropriate tools and follow correct procedures

Maintain accurate records of faults diagnosed.

LO4 **Demonstrate responsibility in the construction, reinstatement and enhancement of the railway track and its environment**

Undertake and supervise:

Ensuring health and safety procedures are always adhered to

Track activities on the railway track infrastructure

Operation of equipment and systems

Installation of assets and equipment

Site clearance

Transferring of asset responsibility upon completion of work.

Validate:

Track renewal and replacement

Use integrity and compliance checks

Appropriate testing has been undertaken.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain railway infrastructure construction, rail technologies and environmental constraints		**D1** Introduce the various interfaces between railway systems and explain how they are interconnected and managed
P1 Describe any preparatory activities that must be undertaken on the railway track prior to the construction of railway infrastructure **P2** Explain the need for safe and healthy work practices and procedures in railway construction	**M1** Analyse the effects of the rail environment has on the safe, secure and uninterrupted operation of a railway with examples	
LO2 Explain the various techniques used in track maintenance, renewal and replacement		**D2** Review the various methods and techniques used in the replacement of components and assets
P3 Identify the track maintenance processes and activities that are used to identify and correct defects on the rail infrastructure **P4** Explain how defects and discrepancies can be identified in various components prior to using them in the construction of rail infrastructure	**M2** Compare the similarities and differences between track renewal and track maintenance activities and give examples for each activity	
LO3 Undertake railway track condition and performance evaluation and troubleshooting		**D3** Explain how detailed data analysis techniques can be used in the diagnosis and troubleshooting of faults in the railway infrastructure
P5 Explain why the performance and condition of the railway track must be monitored **P6** Explain how the rail environment can be monitored	**M3** Assess appropriate types of tests that can be used to diagnose and confirm faults in the railway infrastructure	

Pass	Merit	Distinction
LO4 Demonstrate responsibility in the construction, reinstatement and enhancement of the railway track and its environment.		**D4** Evaluate why integrity and compliance checks must be used to validate construction, reinstatement and enhancement of the railway track and its environment
P7 Describe why track activities on the railway track infrastructure must be supervised **P8** Explain why site clearance must be verified by a supervisor	**M4** Explain why the transferring of assets upon completion of work on the railway infrastructure is necessary	

Recommended Resources

Textbooks

PYRGIDIS, C.N. (2018). *Railway Transportation Systems: Design, Construction and Operation*. London: CRC Press.

SETOLA, R., SFORZA, A., VITTORINI, V. AND PRAGLIOLA, C. (2016). *Railway Infrastructure Security (Topics in Safety, Risk, Reliability and Quality)*. London: Springer.

Links

This unit links to the following related units:

Unit 5: Railway Operations

Unit 10: Introduction to Signalling Systems

Unit 12: Traction and Rolling Stock Systems

Unit 15: Machining and Processing of Engineering Materials

Unit 17: Materials, Properties and Testing

Unit 19: Electro, Pneumatic and Hydraulic Systems

Unit 31: Construction Technology

Unit 32: Surveying, Measuring & Setting Out

Unit 7: Command and Control Systems

Unit code R/617/3664

Unit level 4

Credit value 15

Introduction

The systems that enable a railway to function in an optimum way fall under the area of Command, Control and Communication (CCC). Such railways operate in a safe and timely fashion, and without any delays or cancellations. CCC specialists operate and maintain these systems to ensure the trains operate as planned thus ensuring the passengers enjoy a great service.

This unit focuses on the various systems and subsystems that make up the CCC. Initially, it establishes what CCC is, its purpose and principle of operation. It then goes on to discuss design considerations, such as how health and safety may be embedded into the system, aspects of protection, considers risk and failure modes as well as ergonomic and human factors, IT systems, telecommunications, cybersecurity, and operational and maintenance aspects for the CCC system. The unit then focuses on the Common Safety Method for Risk Evaluation and Assessment (CSM RA), and the European Rail Traffic Management System (ERTMS) and its subsystems: Global System for Mobile Communications – Railway (GSM-R), European Train Control System (ETCS) and European Train Management Layer (ETML).

Students who have completed this unit as part of their HNC studies will be very well placed to apply for employment as Command, Control and Communications (CCC) Advanced Technicians or other similar roles within the railway industry.

Learning Outcomes

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

1. Explain the function of the Control, Command and Communication (CCC) system and the role it plays in the operation of a railway
2. Explore CCC design factors and operational considerations
3. Explain the Common Safety Method (CSM)
4. Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS).

Essential Content

LO1 **Explain the function of the Control, Command and Communication (CCC) system and the role it plays in the operation of a railway**

The Control, Command and Communication (CCC) system:

Determining what the CCC system is

The CCC system function and principle of operation

The function and principle of operation of each CCC subsystem.

Legacy, modern and future rail signalling and train control systems:

Similarities and differences between the various systems.

LO2 **Explore CCC design factors and operational considerations**

Design factors:

Embedding health and safety into the CCC system

Building protection into the design

Risk and failure modes

Ergonomic and human factors

IT systems - architecture, hardware and software

Security technology - cybersecurity considerations, precautions and levels of access

Telecommunications systems.

Operational considerations:

Operational and maintenance requirements

Demonstrating that operational and maintenance requirements are successfully met.

The commissioning certification process:

Designing, implementing and operating a CCC system.

Purpose and processes management:

For data, configuration and change.

LO3 **Explain the Common Safety Method (CSM)**

The need for CSM:

Safety requirements in a competitive environment

Risk evaluation and assessment

Processes harmonisation for risk evaluation and assessment.

Risk management process of CSM RA:

The framework of the risk management process

Analysis and evaluation of hazards

Producing suitable and sufficient risk assessment for a change

Proposing a technical, operational or organisational change.

LO4 **Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS)**

The European Rail Traffic Management System (ERTMS):

The ERTMS system of standards

Purpose, targets and developments

ERTMS function and operation

Implementation and deployment strategies.

The Global System for Mobile Communications – Railway (GSM-R):

Communicating between train and trackside

The GSM-R principle of operation

GSM-R capabilities and limitations

Subsequent communication evolutions.

The European Train Control System (ETCS):

The need for ETCS and its importance to safety

ETCS principle of operation

ETCS numbering levels

Implementation and deployment.

The European Train Management Layer (ETML):

Intelligently optimising train movements

ETML principle of operation and functional structure.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the function of the Control, Command and Communication (CCC) System and the role it plays in the operation of a railway		**D1** Explain how rail signalling and train control systems evolved
P1 Describe the function of the CCC system as used in the railway **P2** Explain the principle of operation of the CCC system	**M1** Explore the principle of operation of the various CCC subsystems	
LO2 Explore CCC design factors and operational considerations		**D2** Justify the importance of incorporating cybersecurity in a CCC system and highlight how the system could be compromised if it gets cyberattacked
P3 Explain the need to embed health and safety aspects in a CCC system during the design phase **P4** Explain why protection must be built in a CCC system during the design phase	**M2** Discuss operational and maintenance requirements in railway CCC systems and explain how they can be successfully met	
LO3 Explain the Common Safety Method (CSM)		**D3** Investigate, with the use of examples, how the CSM RA could be put to use when a technical, operational or organisational change is proposed
P5 Explain why safety requirements were considered a barrier to open competition across EU railways **P6** Explain how CSM RA enables processes harmonisation for risk evaluation and assessment	**M3** Analyse the framework of the CSM RA risk management process explaining three risk acceptance principles	

Pass	Merit	Distinction
LO4 Review the management and interoperability of signalling for railways by the European Rail Traffic Management System (ERTMS)		**D4** Evaluate ERTMS implementation strategies focusing on the main factors that compromised deployment efforts
P7 Describe the problem that the ERTMS was developed to solve **P8** Explain the technical targets of ERTMS	**M4** Evaluate each ETCS and interpret its various numbering levels using a comparative table	

Recommended Resources

Textbooks

HALL, C. (2016) *Modern Signalling Handbook*. 5th ed. Shepperton: Ian Allan Publishing.

YU, F.R. (2018) *Advances in Communications-Based Train Control Systems*. London: CRC Press.

Websites

orr.gov.uk	Office of Rail Regulation Common Safety Method for Risk Evaluation and Assessment (Guidance)
uic.org	Worldwide Railway Organisation ERTMS (Article)
irse.org	Institute of Railway Signal Engineers Technology Updates (General Reference)
ertms.net	ERTMS ERTMS Updates (General Reference)

Links

This unit links to the following related units:

Unit 5: Railway Operations

Unit 10: Introduction to Signalling Systems

Unit 11: Railway Telecommunications

Unit 21: Instrumentation and Control Systems

Unit 26: Management and Operations

Unit 28: Networking

Unit 30: Computer Systems Architecture

Unit 8: Principles of Overhead Power

Unit code	**Y/617/3665**
Unit level	**4**
Credit value	**15**

Introduction

Overhead Line Equipment (OLE) infrastructure is dependent on sound electrical knowledge and ability to follow set procedures declared by authorised Railway Regulatory documentation. This unit is for delegates undertaking Overhead Line Equipment operation and maintenance paths.

The aim of this unit is to build the knowledge and skills, with emphasis on AC and DC technology, used within OLE. Principles are used to build a foundation for engineering knowledge and follow on to safety procedures used in high voltage systems. Students would be expected to take on electrical infrastructure work determined by Electrification Engineers working on specific projects to prove and verify engineering equipment.

The importance of test results depends on data accuracy and correct analytical methods used by project engineers to verify engineering operations in order to manage technical issues raised. The unit also covers the application of electrical principles with instrumentation skills to verify acceptable equipment operation and the continuous supply for railway electrification use.

On successful completion of this unit students will be able to apply the mathematical and engineering skills required to analyse AC signal output from the power supply, identify where a structure failure occurs and find possible solutions while working alongside electrical engineers in a safe manner. Students who have completed this unit as part of their HNC studies will be well placed to apply for employment as an OLE Design Engineer or other similar roles within the rail industry.

Learning Outcomes

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

1. Describe the key characteristics of a magnetic field in electrical power use
2. Explain the operation of a capacitor in an AC circuit including, circuit currents and voltages obtained using practical skills
3. Describe the types and function of capacitors in AC and DC circuits, clearly comparing their uses and differences
4. Determine the sum and difference of two sinusoidal signals with mathematical expressions with different phases.

Essential Content

LO1 **Describe the key characteristics of a magnetic field in electrical power use**

Principles of Electromagnetic Induction:

Faraday's and Lenz's laws

Properties of magnetism applied to a coil

EMF, potential difference and current in a coil using high voltages (HV).

Principles of generators and motors:

Fleming's right- and left-hand rules

Creation of AC waveforms from a generator

Difference in design and use of AC and DC motors.

Transformer Theory for single-, dual- and three-phase supplies

Inductor and Resistive (LR) circuits and impedance (Z).

LO2 **Explain the operation of a capacitor in an AC circuit, including circuit currents and voltages obtained using practical skills**

Key design and construction features and components of capacitors for AC and DC systems:

Types of capacitors (applicable to AC and DC systems)

Construction of a capacitor (polarised and non-polarised)

Charge on a capacitor and hazards in HV uses

Energy stored in a capacitor (AC and DC type of circuits)

Capacitors in series and parallel configuration applications

Comprehension of the difference between actual and calculated total capacitance

Railway applications for multiple capacitors used for rectification.

LO3 **Describe the types and function of capacitors in AC and DC circuits, clearly comparing their uses and differences**

Difference in design calculations and components for AC and DC capacitors:

Charging and discharging of a capacitor in AC circuits and DC circuits
Charging and discharging times using exponential equations to determine waiting times.

DC Transients and RC circuits and Impedance on circuits

Phase difference and phasor diagrams to determine output waveform types

Leading and lagging circuits to control delays in circuit uses.

LO4 **Determine the sum and difference of two sinusoidal signals with mathematical expressions with different phases.**

Complex numbers and resultants using mathematics

Adding two sine waves using oscilloscope for practical method

Adding two sine waves using graphical method

Adding two sine waves using vector method

Subtracting the sine waves that are out of phase

Leading and lagging circuit examples using LRC circuits

Impedance measurement and calculations used to verify it.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the key characteristics of a magnetic field in electrical power use		**D1** Evaluate the main factors of single-, dual- and three-phase AC cables for the operation of overhead power supply
P1 Explain what a sinusoidal waveform is and why it is the preferred method of supplying electrical power **P2** Determine the characteristics of a sinusoidal AC waveform using single phase AC circuit theory including cycle time, Root Mean Square (RMS), peak value and peak to peak values for current and voltages **P3** Explain the relationship between a magnetic and electric field in the supply of electrical power through a single-phase AC cable	**M1** Analyse the effects of a magnetic field between two HV single phase AC cables	
LO2 Explain the operation of a capacitor in an AC circuit, including circuit currents and voltages obtained from a Live circuit		**D2** Critically evaluate the use of earthing cables for HV cable isolation and earthing uses
P3 Explain the construction of a non-polarised capacitor in AC and polarised capacitor in DC application, configured in parallel for total capacitance value **P4** Identify hazards associated with a charged capacitor in HV circuits	**M2** Compare the total capacitance of multiple cables in series and parallel configurations **M3** Discuss the stages required to safely measure the capacitance in HV circuits	

Pass	Merit	Distinction
LO3 Describe the types and function of capacitors in AC and DC circuits, clearly comparing their uses and differences		**D3** Investigate the effect of capacitance and inductance on a single phase HV XLPE power cable
P5 Illustrate how charging and discharging of a capacitor can be determined using calculations **P6** Explain the relationship between the voltage and current for a HV cable with inductive, capacitive and resistive (LRC) circuit	**M4** Justify the use of earthing cables in High Voltage Alternating Current (HVAC) Circuits	
LO4 Determine the sum and difference of two sinusoidal signals with mathematical expressions with different phases.		**D4** Analyse a complex resultant signal and identify the harmonic content present on it
P7 Compare the results of adding and subtracting two in-phase, sinusoidal AC waveforms graphically **P8** Draw the resultant of two out-of-phase AC circuits added and subtracted, using a phasor diagram method	**M5** Create the resultant of two out of phase AC circuits using a spreadsheet and define the characteristics	

Recommended Resources

Textbooks

BARBER, J. and INSTITUTION OF CIVIL ENGINEERS (2002) *Health & Safety in Construction: Guidance for Construction Professionals*. London: Thomas Telford.

BIRD, J. (2004) *Electrical Circuit Theory and Technology*. London: Newnes.

IET. (2010) *Electrical Traction Systems*. London: The Institute of Engineering and Technology.

Websites

www.railway-technical.com	Railway Technical Electric Traction Power (Research)
www.networkrail.co.uk	Network Rail Apprenticeships - What You'll be doing? (General Reference)
www.cablejoints.co.uk	Cable Joints 11Kv-33KV cables XLPE (Research)

Links

This unit links to the following related units:

Unit 5: Rail Operations

Unit 9: Principles of Electrification

Unit 12: Traction and Rolling Stock Systems

Unit 9: Principles of Electrification

Unit code D/617/3666

Unit level 4

Credit value 15

Introduction

Railway infrastructure depends on electrical knowledge and the ability to follow set procedures declared by authorised railway regulatory documentation and standards to suit high voltage environments. The requirements place significant emphasis on electrification technology, including both AC and DC configurations. This unit is fit for students undertaking electrical and plant maintenance, including operation of equipment on railway infrastructure assets.

The unit introduces students to electrical and electronics engineering skills, enabling them to collect and use electrical data from test results used by project engineers to manage technical problems and deal with any issues raised. Electrical principles applied with monitoring systems like SCADA for continuous supply of electricity to railway infrastructure equipment. This involves practical skills and procedures using HV switchgear it will allow the students to identify where and why a structure failure has occurred and find possible solutions through engineering groups.

On successful completion of this unit students pursuing this pathway would take on Electrical infrastructure work in both AC and DC regions, working alongside maintenance and electrical engineers. Students who have completed this unit as part of their Higher National Certificate studies will be well placed to apply for employment as an Electrification Technician or other similar roles within the rail industry.

Learning Outcomes

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

1. Describe rail electrification and power distribution systems and technologies
2. Describe the various features and applications of electrical machines
3. Analyse the various ways of interfacing between rail electrification assets and equipment
4. Explain the principles required to undertake and direct installation, test commission, maintenance and renewal of railway electrification systems.

Essential Content

LO1 **Describe rail electrification and power distribution systems and technologies**

Application, function and operation of assets and equipment:

Electrical components: plugs, sockets, switches, lighting and fittings, junction boxes, relays, protection devices

Compressors: screw piston, rotary vane

Hydraulic motors: piston, gear, vane

Pipework, fittings and manifolds, and their application

Valves: poppet, spool, piston, disc and slide

Sensors and actuators: rotary, linear, mechanical, electrical

Pumps: positive, gear vane and piston.

Electrical hazards, legislation, regulations and standards related to working with electrical apparatus:

Including health and safety in all work practices and procedures

Identifying and managing hazards

Applying control measures to reduce the risk of harm to self

Describing aspects of legislation, regulations and standards.

Properties and behaviour of materials in the rail environment:

Mechanical, physical, thermal, electrical and magnetic.

High voltage and low voltage switchgear, transformers, rectifiers and protection:

Purpose, operation and application

Ensuring plant safety and the requirement to use specialist tools

Hazards associated with the installation and maintenance of switchgear

Component failure modes and causes.

High voltage and low voltage cabling and jointing:

Types of cables: multi-core cables, single-core cables, steel wire armoured (SWA), data cables, screened cables, fibre cables

Types of jointing techniques, their application and operation

Hazards associated with jointing techniques

Cable and joint failure modes and causes.

System appreciation of the following

The effects of short circuit and load flow on the performance of the system

The principles of how communication-electronic or associated systems function and interact e.g. SCADA

Knowledge of compressed air systems

Knowledge of power generation systems as used in the Railway industry

The principles of how Heating Ventilation Air Conditioning (HVAC) units/modules function.

LO2 **Describe the various features and applications of electrical machines**

Features, characteristics and application of alternating current (AC) machines:

AC motors

AC generators

Transformers.

Features, characteristics and applications of direct current (DC) machines:

DC motors

DC generators.

Operation of electrical machine control circuits and systems:

Stop/start/retain relay control circuits for AC or DC machines.

LO3 **Analyse the various ways of interfacing between rail electrification assets and equipment**

Physical and system interfaces of the electrifications systems and the wider rail network:

Overhead line

Electricity supplier DNO, electricity supplier

Switchgear AC and DC

Transformers

Rectifiers

Cabling HV and LV

SCADA

Traction and Rolling Systems

Signalling

Control and communications.

LO4 **Explain the principles required to undertake and direct installation, test commission, maintenance and renewal of railway electrification systems**

Maintaining electrification systems from first principles:

Thermal imaging

Partial discharge

Trending

Condition monitoring

Harmonics

Power quality systems.

Using data analysis to improve the operation and maintenance of power equipment:

Cascading and truth tables

Logic/ladder diagrams

Sequential charts/tables

Functional diagrams.

Undertake and supervise:

Allocation and monitor of resources for electrification and plant engineering activities

Installation of electrification and plant assets

Maintenance on electrification and plant equipment and component

Establish the operational condition of electrification and plant assets

Undertake technical assessment of electrification and plant

Preventative and corrective maintenance of traction cabling systems and maintenance of traction cabling

Switching

Isolation and Earthing

Restoration of contact systems

Thermal imaging and partial discharge

Planning for testing

Transfer responsibility of electrification and plant equipment and components.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe rail electrification and power distribution systems and technologies		**D1** Critically analyse the selection of cables for HV and LV distribution of power to the railway systems
P1 Identify the various design features, processes, equipment and systems used in rail electrification **P2** Explain the function of systems and technologies used in power distribution on railways	**M1** Explore the importance that legislation, regulations and standards have on avoiding electrical hazards	
LO2 Describe the various features and applications of electrical machines		**D2** Investigate the interfacing requirements between electrical machines and associated switchgear and differentiate between AC and DC systems
P3 Explain the principle of operation of electrical machines **P4** Differentiate between the AC and DC electrical machines	**M2** Evaluate the principle operation of electrical machine control circuits and systems defining, where stop/start/retain relay control circuits are used	
LO3 Analyse the various ways of interfacing between rail electrification assets and equipment		
P5 Discuss how rail electrification assets and equipment interface **P6** Differentiate between physical and system interfaces on the wider rail network	**M3** Differentiate between current collection from 25KV AC system and from 750 DC system switchgear	

Pass	Merit	Distinction
LO4 Explain the principles required to undertake and direct installation, test commission, maintenance and renewal of railway electrification systems		**D3** Compare the process of undertaking and supervising the installation of electrification assets and equipment to the scheduled renewal procedure
P7 Describe the principles of undertaking and directing the installation and commissioning of railway electrification systems **P8** Describe the principles of undertaking and directing the maintenance and renewal of railway electrification systems	**M4** Compare the various data analysis techniques used to improve the operation and maintenance of power equipment	

Recommended Resources

Textbooks

BARBER, J. (2002) *Health and Safety in Construction: Guidance for Construction Professionals*. London: Thomas Telford.

BIRD, J. (2010) *Electrical Circuit Theory and Technology*. 4th ed. Oxford: Elsevier.

Websites

www.railway-technical.com	Railway Technical Electric traction power (Research)
www.theiet.org	The Institute of Engineering and Technology Railway electrification (Tutorials)
www.cablejoints.co.uk	Cable Joints 11kV Cable - Single Core XLPE Insulated AWA BS6622 / BS7835 (Research)
www.siemens.com	Siemens Protection relays - Tutorials applications and news (Tutorials)
www.toshiba.co.jp	Toshiba Railway Power Supply Systems System integration (General reference)
www.railjournal.com	International Rail Journal Traction choices: overhead ac vs third rail dc Parliamentary report criticises British electrification policy (Article)

Links

This unit links to the following related units:

Unit 2: Engineering Maths

Unit 5: Railway Operations

Unit 6: Track Design

Unit 8: Principles of Overhead Power

Unit 12: Traction and Rolling Stock Systems

Unit 23: Electrical and Electronic Principles

Unit 25: Electronic Circuits and Devices

Unit 10: Introduction to Signalling Systems

Unit code H/617/3667

Unit level 4

Credit value 15

Introduction

This unit aims to provide students with an underpinning knowledge of signalling, why signalling is provided, and also how it interfaces with other railway engineering disciplines and railway operations.

Students will consider different types of interlocking systems and which train detection systems are used in each type. An appreciation of railway operation will be given when discussing block systems as well as exploring the purpose of signalling from first principles, while considering the necessity for signals and their relationship within the modern railway.

The knowledge and understanding gained in this unit will enable students to make an informed choice should they choose to specialise in signal engineering or, alternatively, a thorough appreciation of the subject should they prefer to pursue other disciplines.

Learning Outcomes

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

1. Evaluate the meaning of signals and indicators provided on UK railways
2. Discuss the merits of various interlocking systems
3. Explore the necessity for train detection systems and how they are applied within the signalling system
4. Identify different types of block systems for single and double line railways.

Essential Content

LO1 **Evaluate the meaning of signals and indicators provided on UK railways**

The development of signals

Historical background from hand signalling by 'policemen' to semaphore signals.

Further development with the greater use of electricity

First with power operation, then development of colour light signals in conjunction with more complex interlocking systems.

Signals in the cab

The migration to cab signalling and indicators

The case for removing wayside signals altogether.

LO2 **Discuss the relative merits of various interlocking systems**

The purpose of interlocking

Historical overview, why it is necessary, what it achieves.

Mechanical interlocking

Principles, use in conjunction with block systems.

Electro-mechanical interlocking

Development from mechanical systems, greater use of electricity within interlocking and wayside signalling.

Electrical interlocking

Types of relay interlockings, comparison with merits of earlier/later interlocking technology, ease of design, installation, test and subsequent modification.

Electronic interlocking

Development of electronic interlockings, principles, management of data, interfacing with other systems, e.g. European Train Control System.

LO3 Explore the necessity for train detection systems and how they are applied within the signalling system

The origin of train detection

Historical overview with early applications

The difference between contacting and non-contacting systems, why it is necessary and what it achieves.

Application of track circuits

Use in conjunction with the absolute block system and subsequent development of the track circuit block system with greater use of centralised control.

Communications Based Train Control (CBTC)

Train detection using radio position reports sent from the train to the wayside equipment as used in moving block systems.

LO4 Identify different types of block systems for single and double line railways.

Block systems

The difference between block systems required for train separation on single line railways and double line railways.

Single line railways

Development from one train working through various systems (staff and token working to acceptance levers) to track circuit block.

Double line railways

Development from time interval working through various systems (absolute block, track circuit block) to moving block systems.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate the meaning of signals and indicators provided on UK railways		**D1** Critically evaluate the reasons for providing different controls for junction signals, considering the advantages and disadvantages of each
P1 Review the evolution of signaling technology from hand signalling through to cab signalling **P2** Assess the implications of cab signaling and indicators on wayside signalling	**M1** Compare and contrast the difference between junction signalling using semaphore signals and colour light signals	
LO2 Discuss the merits of various interlocking systems		**D2** Compare the merits of relay interlocking with earlier/later interlocking technology, considering design, installation, test and subsequent modification
P3 Explore the development of the interlocking systems and the link between points and signals **P4** Determine the advantages and disadvantages between mechanical, electro-mechanical, electrical and electronic interlocking systems	**M2** Assess the use of mechanical signalling in conjunction with block systems	

Pass	Merit	Distinction
LO3 Explore the necessity for train detection systems and how they are applied within the signalling system		**D3** Investigate the differences between track circuits, train detection and CBTC detection, considering the benefits of each
P5 Explore the development of train detection systems and the application of track circuits **P6** Discuss the CBTC system and its importance in communicating the position of the train to the block system wayside equipment	**M3** Assess the uses of train detection with respect to the interlocking and block systems	
LO4 Identify different types of block systems for single and double line railways.		**D4** Critically evaluate the differences between the track circuit block and moving block systems, in particular where application of each of the system would have advantages over the other
P7 Differentiate between the principles of the absolute block system and the track circuit block system **P8** Identify the main characteristics of electric token working for single line railways	**M4** Produce control tables for aspect controls of a junction signal using the track circuit block system	

Recommended Resources

Textbooks

ELLIS, I. (2015) *Ellis' British Railway Engineering Encyclopedia.* 3rd ed. North Carolina: Lulu Press, Inc.

HALL, C. (2019) *abc Modern Signalling Handbook.* 5th ed. Shepperton: Ian Allan Publishing.

WOODBRIDGE, P.J. (2018) *A Chronology of UK Railway Signalling 1825 – 2018.* London: Independent Publishing Network.

Websites

rssb.co.uk	Rail Safety and Standards Board Standards catalogue (General Reference)
irse.org	Institution of Railway Signal Engineers Knowledge (General Reference)
signalling-and-telecommunications.uk	Signal & Telecommunications UK Trainee revision questions Training
signalbox.org	Railway signalling Signals (General Reference)

Links

This unit links to the following related units:

Unit 5: Railway Operations

Unit 7: Command and Control Systems

Unit 11: Railway Telecommunications

Unit 12: Traction and Rolling Stock Systems

Unit 23: Electrical and Electronic Principles

Unit 28: Networking

Unit 29: Strategic Information Systems

Unit 11: Railway Telecommunications

Unit code K/617/3668

Unit level 4

Credit value 15

Introduction

Telecommunications is one of the most important areas in the successful running of a railway system. It provides the infrastructure which supports not just the communication between train operators and other members of staff or passengers, but also the signalling which enables the safe control of operational aspects of the railway as well as the monitoring of various parameters, including environmental ones, for security purposes.

This unit focuses on the principles, technology, systems, design, maintenance and troubleshooting of telecommunications systems as they apply in the railway industry. Initially, the unit covers circuits, analogue and digital signals, modulation and multiplexing. A basic communications system is then introduced and analysed, and various technologies are presented: fixed and mobile telephony, copper-based systems, fibre optics, microwave links and satellite communications. This is followed by telecommunications systems, interfacing and operating procedures as they apply to the railway industry. Finally, the unit focuses on all stages of designing, installing, testing, maintaining and troubleshooting a telecommunications system based on a brief specific to the railway industry.

Students who have completed this unit as part of their HNC studies will be very well placed to apply for employment as Telecommunications Advanced Technicians or other similar roles within the rail industry.

Learning Outcomes

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

1. Explain telecommunications principles and technology fundamentals
2. Describe various types of telecommunications systems and technologies
3. Explore how telecommunications systems are employed in the railway industry
4. Explore the principles of design, installation, commissioning, maintenance and troubleshooting of railway telecommunications systems.

Essential Content

LO1 **Explain telecommunications principles and technology fundamentals**

Circuits:

Open and closed circuits

Ohm’s Law.

Signals:
Electromagnetic (EM) spectrum
Analogue signal characteristics – amplitude, frequency, period, velocity
Digital signal characteristics – amplitude, bit rate, baud rate
Analogue-to-Digital and Digital-to-Analogue Conversion (ADC and DAC), Sampling, digitising, line encoding, data codes.

Modulation:
Analogue carrier modulation – AM, FM, PM
Digital carrier modulation – ASK, FSK, PSK.

Multiplexing:
Frequency, time and wavelength Division Multiplexing (FDM, TDM, WDM).

LO2 **Describe various types of telecommunications systems and technologies**

Basic communications system:
Transmitter, channel, receiver
Communications channel – wired and wireless
Signal transmission – strength, noise, attenuation, bandwidth, dB, SNR.

Telecommunications technologies:
Public Switched Telephone Network (PSTN)
Mobile / cellular telephony
Fibre optic communications
Free Space Optical (FSO) Communications
Microwave point-to-point links
Satellite communications.

Data communications:
Data flows, encapsulation, collisions
ISO/OSI 7-Layer and TCP/IP Reference Models
Networks (PAN, LAN, MAN, WAN, etc)
The internet.

LO3 **Explore how telecommunications systems are employed in the railway industry**

Railway telecommunications systems:
Communication between railway staff
Traffic safety, traffic reliability and time synchronisation
Customer information systems, passenger alarms, internet, video surveillance.

Interfacing between similar and different telecommunications assets and systems:
Physical interfaces
Systems interfaces.

Telecommunications operating procedures:
Fail-safe operation principles
Emergency procedure responses
Health and safety.

Safety Integrity:
Safety critical systems
Process assurance
Systematic failure integrity
Safety Integrity Levels (SIL)
Controlling hazards during operation
Safe work practice procedures.

LO4 **Explore the principles of design, installation, commissioning, maintenance and troubleshooting of railway telecommunications systems**

Brief/Application/System Requirements:

Determining specifications

Identifying implications and constraints

Establishing operating requirements.

Telecommunications system design:

Planning based on specifications

Choosing an appropriate telecommunication technology

Producing a telecommunications system design.

Installation Procedures:

Planning

Safeguarding

Installing

Testing

Delivering.

Maintenance:

Determining appropriate maintenance procedures and frequencies.

Troubleshooting:

Faultfinding using appropriate techniques and procedures

Repairing, testing, returning to service.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain telecommunications principles and technology fundamentals		**D1** Investigate the process of ADC and DAC, presenting graphical representations of conversions and effects from sampling and quantisation noise on the recovered analogue signal
P1 Describe telecommunications principles with respect to circuit design and signals **P2** Explore the telecommunications technological fundamentals in terms of modulation and multiplexing	**M1** Compare analogue and digital signals giving, the choice of signal for long-distance communications	
LO2 Describe various types of telecommunications systems and technologies		**LO2 and LO3** **D2** Analyse the various telecommunications systems used on trains to enable passengers to access the internet describing the factors which affect the quality of service provision.
P3 Explain a simple telecommunications system detailing the functions of each stage **P4** Discuss the effects that a wireless channel has on a telecommunication system's capabilities	**M2** Illustrate the process of encapsulation and decapsulation in data communications along with which networking devices are associated with each step	
LO3 Explore how telecommunications systems are employed in the railway industry		
P5 Explain how telecommunications is used to support and enhance traffic safety, traffic reliability and time synchronisation **P6** Describe what part telecommunications plays in maintaining operational procedures and safety integrity in the railway industry	**M3** Assess the different types of telecommunications systems used in the railway industry	

Pass	Merit	Distinction
LO4 Explore the principles of design, installation, commissioning, maintenance and troubleshooting of railway telecommunications systems.		**D3** Develop a maintenance programme that would reduce the down time of a telecommunications system, highlighting the design features that could significantly impact schedules
P7 Explain the process of developing a telecommunications system from design conception through to commissioning **P8** Discuss the importance of railway telecommunication systems maintenance and troubleshooting	**M4** Evaluate the impacts that telecommunication system design has on maintenance and troubleshooting	

Recommended Resources

Textbook

FRENZEL, L.E. JR. (2016) *Principles of Electronic Communication Systems*. 4th ed. New York: McGraw-Hill Education.

MASSON, E. and BERBINEAU, M. (2018) *Broadband Wireless Communications for Railway Applications: For Onboard Internet Access and Other Applications (Studies in Systems, Decision and Control)*. Berlin: Springer.

STALLINGS, W. (2013) *Data and Computer Communications.* 10th ed. Harlow: Pearson.

YU, F. R. (2018) *Advances in Communications-Based Train Control Systems*. Boca Raton: CRC Press.

ZHONG, Z.D., AI, B. and ZHU, G. (2017) *Dedicated Mobile Communications for High-speed Railway (Advances in High-speed Rail Technology)*. Berlin: Springer.

Websites

theiet.org	The IET Railway Network
	Railway
	(General Reference)
railjournal.com	International Railway Journal
	Technology updates
	(General Reference)
railway-technical.com	Railway Technical
	Technology updates
	(General Reference)

Links

This unit links to the following related units:

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 5: Railway Operations

Unit 7: Command and Control Systems

Unit 10: Introduction to Signalling Systems

Unit 12: Traction and Rolling Stock Systems

Unit 23: Electrical and Electronic Principles

Unit 24: Digital Principles

Unit 25: Electronic Circuits and Devices

Unit 28: Networking

Unit 29: Strategic Information Systems

Unit 12: Traction and Rolling Stock Systems

Unit code M/617/3669

Unit level 4

Credit value 15

Introduction

Rolling stock (trains) are made up of traction and passenger carriages for people and locomotives and wagons for cargo. Traction and Rolling Stock Systems Advanced Technicians maintain and repair these so they operate safely and efficiently. Most of the work takes place at night when the railway is closed to the public.

This unit focuses on the knowledge and skills that Traction and Rolling Stock Systems Advanced Technicians must have on the design, construction, maintenance, operation and failure modes of the railway. The unit provides in-depth and detailed technical knowledge of traction and rolling stock systems, subsystems and components, and how they interact. It considers mechanical, electrical, electronic, pneumatic and hydraulic applications. It provides in depth understanding of maintenance procedures and standards as applicable to vehicle type; emphasises the requirement to isolate equipment prior to carrying out maintenance and renewal of traction and rolling stock; delivers knowledge on the requirements of and planning for vehicle overhaul, the physical and systems interfaces between traction and rolling stock assets and systems, and other aspects of the railway, the operating requirements, and the implications and constraints of these.

Upon completing this unit, Traction and Rolling Stock Systems Advanced Technicians will also be able to interrogate and understand advanced diagnostic systems, and analyse data packages to identify and understand faults and potential faults and defects. Moreover, they will also be able to implement corrective actions to enhance vehicle reliability and to recommend design alterations and amendments to maintenance procedures in accordance with current rail legislation.

Learning Outcomes

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

1. Explain traction and rolling stock systems, subsystems and components and how they interact
2. Explore the different techniques and methods used to construct, install and manage traction and rolling stock systems and avoid failures
3. Explain the principles required to maintain, renew and troubleshoot the traction and rolling stock systems
4. Explore effective maintenance procedures and standards relative to a particular type of traction and rolling stock.

Essential Content

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

Systems and components:

Mechanical components and systems

Electrical components and systems

Hydraulic and pneumatic components and systems

Ancillary equipment

Heat Ventilation and Air Conditioning (HVAC)

Vehicle trim and fittings

Other vehicle equipment and furnishings

Electronic communication systems and associated equipment.

LO2 **Explore the different techniques and methods used to construct, install and manage traction and rolling stock systems and avoid failures**

Techniques and methods used to construct, install and manage:

Suspension and tilt systems

Stock braking systems

Axles, wheels and bearings

AC and DC electric power collection and transmission

Diesel hydraulic and diesel electric power generation and transmission in overground trains.

Techniques and methods used to avoid railway asset, equipment, process and systems failures:

Data analysis

Health and safety precautions

Maintenance schedules

Fault testing and diagnosis

Use of appropriate tools and equipment

Troubleshooting techniques

Maintenance record and fault-logging system.

LO3 **Explain the principles required to maintain, renew and troubleshoot the traction and rolling stock systems**

Techniques and methods used to maintain, renew and troubleshoot:

Suspension and tilt systems

Braking systems

Axles, wheels and bearings

AC and DC electric power collection and transmission

Overground train diesel hydraulic and diesel electric power generation and transmission.

Overground and underground vehicle passenger comfort, safety and security:

Closed Circuit Television Systems (CCTV)

Heating, Ventilation and Air Conditioning Systems

Passenger information systems

Interior and exterior, saloon and cab door systems

Toilet systems

Vehicle trim.

Traction motors

System knowledge

Various control systems and components

Principles of systems functions

Correct operating procedures.

LO4 **Explore effective maintenance procedures and standards relative to a particular type of traction and rolling stock**

Carry out maintenance and overhaul activities:

Isolation of equipment prior to carrying out maintenance for health and safety reasons

Operating in a timely and specified sequence

Specific to the equipment being maintained

Set up and apply the appropriate test equipment

Troubleshooting and overcoming problems

Plan and communicate the maintenance activities to ensure minimal disruption to normal working

Replenish levels of fluid power components

Fault-finding activities on traction and rolling stock systems, process-controller systems and electrical equipment

Ensure activities comply with relevant standards.

Dismantling, re-assembling and replacing equipment:

Use appropriate operating and maintenance procedures for equipment and components.

Maintenance of connections and fittings:

In accordance with maintenance schedule

Regular mechanical connections checks

Ensure secure electrical and electronic connections

Ensure secure hydraulic and pneumatic connections.

Undertake testing activities:

Specific to item tested.

Follow correct handover procedures

Documentation sign-off

Approval of service.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain traction and rolling stock systems, subsystems and components and how they interact		**D1** Critically analyse how the various traction and rolling stock systems interface, identifying any specific systems that interact with passengers
P1 Describe traction and rolling stock systems and components **P2** Discuss the function of the various components and systems and how they interact	**M1** Illustrate the function of the various electronic communication systems and their associated equipment that operate with the traction and rolling systems	
LO2 Explore the different techniques and methods used to construct, install and manage traction and rolling stock systems and avoid failures		**D2** Develop a maintenance schedule aimed at optimising rolling stock operation while avoiding railway asset, equipment, process and systems failures
P3 Identify the construction stages, techniques and procedures used for traction and rolling stock systems **P4** Assess why it is important to follow health and safety precautions when constructing, installing and managing traction and rolling stock systems	**M2** Evaluate the various techniques and methods used to construct, install and manage traction and rolling stock systems with regard to failure prevention	
LO3 Explain the principles required to maintain, renew and troubleshoot the traction and rolling stock systems		**D3** Analyse how AC and DC electric power collection and transmission systems maintenance must be undertaken
P5 Describe the importance of following the maintenance schedule when maintaining and renewing traction and rolling stock systems **P6** Explain what approaches are used when troubleshooting traction and rolling stock system issues	**M3** Explain the importance of and the principles required to undertake and direct the maintenance of Heating, Ventilation and Air Conditioning Systems	

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO4 Explore effective maintenance procedures and standards relative to a particular type of traction and rolling stock</td><td rowspan="2">D4 Explain two types of testing activities undertaken to confirm that traction and rolling stock systems operate correctly</td></tr>
<tr><td>P7 Explain why it is necessary to isolate equipment prior to carrying out maintenance

P8 Explain how frequent and timely maintenance of the railway helps prevent railway asset, equipment, process and systems failures especially with regard to logging faults and findings</td><td>M4 Explain why electrostatic discharge (ESD) precautions must be taken when working on or close to sensitive electronic communications components</td></tr>
</table>

Recommended Resources

Textbooks

IWNICKI, S. (Ed.) *Handbook of Railway Vehicle Dynamics*. Boca Raton: CRC Press.

PYRGIDIS, C.N. (2018). *Railway Transportation Systems: Design, Construction and Operation.* Boca Raton: CRC Press.

Websites

www.railway-technical.com	Railway – Technical
	Trains (General Reference)
www.imeche.org	IMechE Railway Railway (General Reference)
www.hitachirail-eu.com	Hitachi Rail Depots (General Reference)

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 5: Railway Operations

Unit 6: Track Design

Unit 7: Command and Control Systems

Unit 9: Principles of Electrification

Unit 10: Introduction to Signalling Systems

Unit 11: Railway Telecommunications

Unit 13: Passenger Safety and Security

Unit 19: Electro, Pneumatic and Hydraulic Systems

Unit 20: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit 21: Instrumentation and Control Systems

Unit 22: Quality and Process Improvement

Unit 23: Electrical and Electronic Principles

Unit 13: Passenger Safety and Security

Unit code **H/617/3670**

Unit level **4**

Credit value **15**

Introduction

Essential to the ability for people to travel the length and breadth of the country is the provision of a safe, reliable and resilient transport network. Most countries across the world, including the UK, the USA, China, Japan and Germany, benefit from extensive rail networks. Successfully operated, these networks help to reduce traffic congestion on highways, reduce the need for air travel, promote commerce and benefit the environment.

Ensuring that the overground passenger rail networks are comfortable, safe and secure encourages their continued use by passengers. Passengers must receive clear information on approaching stations, disruptions to rail services and instructions in the event of an emergency while travelling. Overground rail carriages are ventilated and maintained at a suitable temperature for users. Customers board and alight rail carriages speedily, mostly using automatic doors, and are monitored using closed-circuit television whilst on trains to ensure their own safety.

This unit enables students to develop their knowledge of the purpose, installation, use and maintenance of different types of passenger comfort, safety and security systems. Passenger information systems and the communication systems are examined and maintained along with other systems integral to the safety and comfort of passengers. These systems include railway doors, Heating Ventilation and Air Conditioning (HVAC), toilets and the vehicle trim used on rail vehicles.

The unit introduces both the electrical and pneumatic control systems used on overground rail vehicles and, on completion, the student will have a greater understanding of key passenger safety and security systems and how they function.

On successful completion of this unit students will be able to prepare an engineering design specification that fulfils a stakeholder's design brief, recommend reliability improvements and present these to an audience. Students will also be able to demonstrate an understanding of the required legislation in the areas of passenger safety and security and use this understanding to formulate solutions to overcome maintenance issues. Students who have completed this unit as part of their HNC studies will be well placed to apply for employment as Rolling Stock Testing Support, Rolling Stock Technical Engineer or other similar roles within the rail industry.

Learning Outcomes

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

1. Explain how modifications to an existing fleet of rolling stock with improved passenger safety or security equipment can be made in response to a stakeholder's design brief
2. Investigate the feasibility and cost implications of installing a universal access toilet in an area currently used for passenger seating
3. Describe possible solutions that would enable a train maintenance facility to repair, modify and re-gas its own HVAC systems on site
4. Analyse possible design solutions that propose a reliability improvement to an exterior saloon door or cab door system.

Essential Content

LO1 **Explain how modifications to an existing fleet of rolling stock with improved passenger safety or security equipment can be made in response to a stakeholder's design brief**

Planning techniques used to prepare a design solution:

Definition of any design constraints, specifications, assumptions and functions

Use of relevant engineering/industry standards and specifications within the design process

Use of ergonomic and aesthetic standards and specifications in the design of passenger equipment and comfort

Planning the design task using flow charts, Gantt charts, network and critical path analysis.

Design process:

Process development, steps to consider from start to finish.

Key components of passenger information systems their operation and function:

Public address systems

Passenger information and safety signage and displays

Passenger emergency alarms

Communication networks

Coach design variations due to passenger class requirements

Seat reservation plan and display.

Components, function and technical requirements of closed-circuit television systems:

Explain the different types of cameras and systems, their characteristics, capabilities and positioning, including communication networks.

Appropriate use of closed-circuit television to respect privacy:

Data Protection Act 1988

Human Rights Act 1988

Freedom of Information Act 2000

Impact of the Information Commissioner's Code of Practice on the operation of closed-circuit television systems and the requirements of privacy zones.

Understanding customer/stakeholder requirements:

Converting customer requests to a list of objectives and constraints

Interpretation of design requirements.

Market analysis of existing products and competitors

Aspects of innovation and performance management in decision-making.

LO2 **Investigate the feasibility and cost implications of installing a universal access toilet in an area currently used for passenger seating**

Components of a train toilet system:

Waste and fresh water systems

Soap dispenser and hygiene systems

Processors

Vacuum control

Cabling

Pipework

Call-for-aid systems

Toilet module size and space requirements and optimisation

Fresh water replenishment and waste tank emptying requirements.

Seating loss and passenger capacity:

Potential revenue loss

Passenger dissatisfaction.

Legislation and regulations:

Specification for toilets of railway vehicles

Accessibility requirement

Technical specification for interoperability relating to persons with reduced mobility

Association of Train Operating Companies (ATOC) guidance.

Design process:

Process development

Steps to consider from start to finish.

Planning techniques used to prepare a design solution:

Definition of any design constraints, assumptions specifications and functions

Use of relevant engineering/industry standards within the design process

Planning the design task using flow charts, Gantt charts, network and critical path analysis.

LO3 **Describe possible solutions that would enable a train maintenance facility to repair, modify and re-gas its own HVAC systems on site**

Legislation and regulations related to:

Refrigerant handling

Storage and disposal

Competence

Safe systems of work, including potential hot work permits.

Working on or around live electrical systems:

Importance of safety

Risk management

Understanding of the Electricity at Work Regulations 1989.

Working on or around pressurised systems:

Importance of safety

Risk management

Understanding the Pressure Equipment Regulations 1999 (PER)

Understanding the Pressure Systems Safety Regulations 2000 (PSSR).

LO4 **Analyse possible design solutions that propose a reliability improvement to an exterior saloon door or cab door system.**

Communication and post-presentation review:

Selection of presentation tools

Analysis of presentation feedback

Strategies for improvement based on feedback.

Key components of exterior saloon and cab door:

Importance of correct set-up

Electric/electro-pneumatic sliding and plug doors

Lock mechanisms and their control systems

Safety systems both local to the door and train wide.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain how modifications to an existing fleet of rolling stock with improved passenger safety or security equipment can be made in response to a stakeholder's design brief		**D1** Critically Analyse potential planning and design requirements, giving a justification for the chosen method
P1 Describe how modifications to improve passenger safety or security can be made from a given design brief **P2** Discuss how a customer's request can be converted to a list of design objectives and constraints	**M1** Analyse how the existing external rolling stock design could present limitations on the design of the internal equipment	
LO2 Investigate the feasibility and cost implications of installing a universal access toilet in an area currently used for passenger seating		**D2** Evaluate the implications that the installation of a toilet will have on the HVAC system's design with regards to capacity and HSE requirements
P3 Explore the feasibility of carrying out the proposed task **P4** Explain the cost implications of the scope of work	**M2** Examine the optimisation process required to maximise the area taken up by the toilet whilst minimising the impact on the original passenger seating area	
LO3 Describe possible solutions that would enable a train maintenance facility to repair, modify and re-gas its own HVAC systems on site		**D3** Evaluate the proposed maintenance solution with regards to the option of outsourcing
P5 Outline the requirements of servicing HVAC units in a depot environment **P6** Illustrate possible design solutions **P7** Identify the legal and safety implications of carrying out the full scope of maintenance work	**M3** Analyse the time and cost implications of the maintenance solution	

Pass	Merit	Distinction
LO4 Analyse possible design solutions that propose a reliability improvement to an exterior saloon door or cab door system.		**D4** Justify potential improvements to the presented design solution, based on reflection and feedback obtained from the presentation
P8 Illustrate possible design solutions to improve the reliability of an exterior saloon or cab door system **P9** Propose a reliability improvement to either an exterior saloon or cab door system **P10** Present the recommended design solution to the identified audience	**M4** Compare the effectiveness of the possible design solutions	

Recommended Resources

Textbooks

BONNETT, C. F. (2005) *Practical Railway Engineering*. 2nd ed. London: Imperial College Press.

Textbooks

www.transportfocus.org.uk	Transport Focus Future Merseyrail rolling stock – what passengers want (Publication)
www.hse.gov.uk	Health and Safety Commission Rail safety: Proposals for Regulations on train protection systems and mark 1 rolling stock (Report)
orr.gov.uk	Office of Rail and Road Passenger Safety (General reference)

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 5: Railway Operations

Unit 11: Railway Telecommunications

Unit 12: Traction and Rolling Stock Systems

Unit 17: Materials Properties and Testing

Unit 19: Electro, Pneumatics and Control Systems

Unit 21: Instrumentation and Control Systems

Unit 26: Management and Operations

Unit 14: Renewable Energy

Unit code F/615/1479

Unit level 4

Credit value 15

Introduction

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

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

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

**This unit is the same unit as Unit 5: Renewable Energy in the Pearson BTEC Higher Nationals in Engineering*

Learning Outcomes

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

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

Essential Content

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

Alternative energy sources, their respective merits and drawbacks:

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

Waste as energy

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

Energy demand and security of supply:

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

Factors affecting changes in energy consumption and demand

Future demand planning based on trends and needs analysis

Risk analysis for energy supplies for UK and local areas

Energy capacity margins analysis related to changes in demand

Alternatives for locally used energy sources

Energy reduction and efficiency approaches:

Energy systems available for a given location

Energy legislation and standards

Energy saving and reduction schemes, energy saving technologies available

Energy efficiency approaches for domestic energy use

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

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

Financial and environmental implications:

Cost–benefit analysis

Socio-economic factors

Financial implications of renewable and conventional energy

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

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

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

Evaluation planning tools such as PESTLE analysis

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explore potential renewable energy resources, including current storage and generation technologies</td><td rowspan="2">D1 Provide supported and well justified recommendations for the adoption of the most widely used conventional and non-conventional renewable energy resources</td></tr>
<tr><td>P1 Create schematic diagrams showing the working principle of the most widely used renewable energy systems</td><td>M1 Explore the rates of adoption of the most widely used renewable energy resources</td></tr>
<tr><td colspan="2">LO2 Determine the optimum combination and efficiencies of renewable energy technologies for a particular location</td><td rowspan="2">D2 Summarise the efficiencies of a variety of combinations of renewable energy technologies for a chosen location</td></tr>
<tr><td>P2 Describe how each renewable energy system could be connected with local energy systems</td><td>M2 Discuss how renewable energy systems will bring benefit to the people living in the chosen area</td></tr>
<tr><td colspan="2">LO3 Conduct a cost–benefit analysis to determine the most viable option between renewable and conventional energy sources</td><td rowspan="2">D3 Conduct a cost–benefit critical analysis to determine the most viable option between all available renewable and conventional energy sources</td></tr>
<tr><td>P3 Calculate the installation and construction costs of one renewable energy system from a renewable energy standpoint</td><td>M3 Contrast the installation and construction costs of all available renewable energy sources</td></tr>
<tr><td colspan="2">LO4 Explain socio-economic, legislative and environmental factors involved in the consideration and selection of other approaches to renewable energy resources and technologies</td><td rowspan="2">D4 Provide supported and justified recommendations and original ideas for an effective environmental analysis of alternative approaches to the selection of renewable energy resources</td></tr>
<tr><td>P4 Examine how socio-economic, legislative and environmental factors affect the selection, set-up and operation of renewable energy sources</td><td>M4 Evaluate environmental analysis and planning tools such as PESTLE to identify possible sources of conflicts of interest</td></tr>
</table>

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.

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 3: Engineering Science

Unit 4: Managing a Professional Engineering Project

Unit 15: Machining and Processing of Engineering Materials

Unit code	**A/615/1481**
Unit level	**4**
Credit value	**15**

Introduction

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

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

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

**This unit is the same unit as Unit 7: Machining and Processing of Engineering Materials in the Pearson BTEC Higher Nationals in Engineering*

Learning Outcomes

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

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

Essential Content

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

Conventional processes:

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

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

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

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

Safe working practices when operating machining and process forming equipment

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

Material choice and machine process:

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

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

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

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

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

Awareness of the range of cutting tools:

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

Properties for cutting tool materials

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

Cutting forces and the mechanics of chip formation:

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

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

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

Work-holding: six degrees of freedom

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

Moulding and shaping processes:

Range of metal and ceramic powder moulding and shaping processes

Casting, powder metallurgy and sintering

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

Range, benefits and limitations of various shaping processes:

Extrusion, forging, rolling, hot and cold presswork

Range of casting processes:

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore the conventional machining and forming processes and their application in the production of engineered components		**D1** Determine the benefits and limitations of components manufactured using conventional machining and moulding processes
P1 Describe the most appropriate machining process to manufacture a selected product **P2** Explain why a specific machining process would be used to manufacture a selected component	**M1** Examine the characteristics of conventional machining processes, plastic moulding processes and powder metallurgy	
LO2 Explain how component materials, metals and non-metals, affect the selection of the most appropriate machining or forming process		**D2** Review the structure and mechanical properties of a given engineered aluminium alloy component, manufactured using the die casting process and conventional material removal machining processes
P3 Describe how the manufacturing process can affect the structure and properties of the parent material **P4** Describe the effect lubricants, coolants and cutting fluids have on tooling, production speed, and quality of finish	**M2** Detail the characteristics of cutting tool geometries **M3** Explain why different tool geometries are required for polymer, composite and carbon steel materials	
LO3 Identify the most appropriate machine tooling, jigs and fixtures to support the production of an engineered component		**D3** Examine the relationship between cutting speed and tool life on the economics of metal removal
P5 Review the parameters that determine the appropriate tooling for the production of a given engineered component **P6** Describe the six modes of cutting tool failure	**M4** Explain the properties and applications of ceramics tools and cubic boron nitride tools	

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

Recommended Resources

Textbooks

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

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

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 16: Mechanical Principles

Unit 17: Materials, Properties and Testing

Unit 16: Mechanical Principles

Unit code F/615/1482

Unit level 4

Credit value 15

Introduction

Mechanical principles have been crucial for engineers to convert the energy produced by burning oil and gas into systems to propel, steer and stop our automobiles, aircraft and ships, 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

**this unit is the same as Unit 8: Mechanical Principles from Pearson BTEC HIGHER Nationals in General Engineering*

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
LO1 Identify solutions to problems within static mechanical systems		**D1** Calculate the magnitude of shear force and bending moment in cantilever and encastré beams for a variety of applications
P1 Calculate the distribution of shear force, bending moment and stress due to bending in simply supported beams **P2** Justify the selection of standard rolled steel sections for beams and columns **P3** Determine the distribution of shear stress and the angular deflection due to torsion in solid and hollow circular shafts	**M1** Determine the material of a circular bar from experimental data of angle of twist obtained from a torsion test	
LO2 Illustrate the effects that constraints have on the performance of a dynamic mechanical system		**D2** Calculate solutions of velocities and accelerations within planar mechanisms using trigonometric methodology
P4 Explain the effects of energy transfer in mechanical systems with uniform acceleration present **P5** Identify the magnitude and effect of gyroscopic reaction torque	**M2** Construct diagrams of the vector solutions of velocities and accelerations within planar mechanisms	
LO3 Investigate elements of simple mechanical power transmission systems		**D3** Examine the cause of a documented case of mechanical power transmission failure and the steps taken to correct the problem and rectify any design faults
P6 Determine the velocity ratio for compound gear systems and the holding torque required to securely mount a gearbox **P7** Calculate the operating efficiency of lead screws and screw jacks **P8** Explain the conditions required for a constant velocity ratio between two joined shafts	**M3** Examine devices which function to store mechanical energy in their operation	

Pass	Merit	Distinction
LO4 Analyse natural and damped vibrations within translational and rotational mass-spring systems		**D4** Identify the conditions needed for mechanical resonance and measures that are taken to prevent this from occurring
P9 Explain the natural frequency of vibration in a mass-spring system	**M4** Determine the amplitude and phase angle of the transient response within a mass-spring-damper system	

Recommended Resources

Textbooks

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

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

Websites

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

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 17: Materials Properties and Testing

Unit 17: Materials, Properties and Testing

Unit code J/615/1483

Unit level 4

Credit value 15

Introduction

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

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

On successful completion of this unit students will be able to explain the relationship between the atomic structure and the physical properties of materials, determine the suitability of engineering materials for use in a specified role, explore the testing techniques to determine the physical properties of an engineering material and identify the causes of in-service material failure.

**this unit is the same as Unit 9: Materials, Properties and Testing from Pearson BTEC HIGHER Nationals in General Engineering*

Learning Outcomes

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

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

Essential Content

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

Physical properties of materials:

Classification and terminology of engineering materials

Material categories: metallic, ceramic, polymer and composites

Atomic structure, electrostatic covalent and ionic bonding

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

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

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

Materials used in specific roles:

The relationship between product design and material selection

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

The effect heat treatment and mechanical processes have on material properties

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

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

LO3 **Explore the testing techniques to determine the physical properties of an engineering material**

Testing techniques:

Destructive and non-destructive tests used to identify material properties

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

Most appropriate tests for the different categories of materials

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

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

Material failure:

Reasons why engineered components fail in service

Working and environmental conditions that lead to material failure

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

Reasons for failure in service

Preventative measures that can be used to extend service life

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explain the relationship between the atomic structure and the physical properties of materials</td><td rowspan="2">D1 Explain how composition and structure of materials influence the properties of the parent material across the material’s range</td></tr>
<tr><td>P1 Describe the crystalline structure of the body-centred cubic cell, face-centred cubic cell and hexagonal close packed cell

P2 Identify the different material properties that are associated with amorphous and crystalline polymer structures</td><td>M1 Describe physical, mechanical, electrical and thermal material properties, identifying practical applications for each property if it were to be used in an engineering context</td></tr>
<tr><td colspan="2">LO2 Determine the suitability of engineering materials for use in a specified role</td><td rowspan="2">D2 Explain why the behaviour of materials is considered such an important factor when selecting a material for a given product or application</td></tr>
<tr><td>P3 Provide a list of the four materials categories, including an example of a product and application for each material identified

P4 Identify the specific characteristics related to the behaviour of the four categories of engineering materials</td><td>M2 Describe, with examples, the effect heat treatment and mechanical processes have on material properties</td></tr>
<tr><td colspan="2">LO3 Explore the testing techniques to determine the physical properties of an engineering material</td><td rowspan="2">D3 Analyse the results of mechanical tests on each of the four material categories for data comparison and compare results against industry recognised data sources, explaining any differences found</td></tr>
<tr><td>P5 Describe the six most common tests used to identify material properties

P6 Describe the non-destructive testing processes – dye penetrant, magnetic particle, ultrasonic and radiography – and include an example application for each</td><td>M3 Explain how test results influence material selection for a given application</td></tr>
</table>

Pass	Merit	Distinction
LO4 Recognise and categorise the causes of in-service material failure		**D4** Explain the methods that could be used for estimating product service life when a product is subject to creep and fatigue loading
P7 Describe six common mechanisms of failure **P8** Describe working and environmental conditions that lead to failure for a product made from material from each of the four material categories	**M4** Explain, with examples, the preventative measures that can be used to extend the service life of a given product within its working environment	

Recommended Resources

Textbooks

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

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

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 16: Mechanical Principles

Unit 18: Engineering Management

Unit code Y/615/1486

Unit level 4

Credit value 15

Introduction

Managing engineering projects is one of the most complex tasks in Rail 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.

**This unit is the same as Unit 12: Engineering Management from Pearson BTEC Higher Nationals in Engineering*

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 Rail 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 Rail Engineering organisations**

Fundamentals of quality management:

Introduction to monitoring and controlling

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

Risk and quality management:

Risk management processes

Risk mapping and risk matrix

Quality management theories

Continuous improvement practices

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

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

Operation management:

Main areas and stages of projects and operations management

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

Project and operations management theories and tools:

Project appraisal and life cycle

Logistics and supply chain management

Operations management

Resources management

Sustainability

Legal requirements governing employment, health, safety and environment

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

The key success of management strategies:

Following processes from end to end, from suppliers to customers

Identifying areas critical for the success of a project or process

Planning tools:

Gantt charts

Flow charts

Critical analysis and evaluation

Learning Outcomes and Assessment Criteria

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

Recommended Resources

Textbooks

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

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

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

Websites

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

Links

This unit links to the following related units:

Unit 4: Managing a Professional Engineering Project

Unit 26: Management and Operations

Unit 19: Electro, Pneumatic and Hydraulic Systems

Unit code L/615/1498

Unit level 4

Credit value 15

Introduction

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

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

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

**This unit is the same unit as Unit 29: Renewable Energy in the Pearson BTEC Higher Nationals in Engineering*

Learning Outcomes

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

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

Essential Content

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

Pneumatic and hydraulic theory:

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

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

System performance, volumetric operational and isothermal efficiency

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

Performance of hydraulic and pneumatic components:

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

Fluid power diagrams

Pneumatic and hydraulic critical equipment and their purpose

Circuit diagrams, component interaction and purpose

Dynamics of modern system use

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

System applications:

Calculation of appropriate capacities and specifications

Applied functions of control elements

Design and testing of hydraulic and pneumatic systems

Fluid power in real-life examples

Valued component choice

LO4 **Investigate the maintenance of pneumatic and hydraulic systems**

Efficiency of systems:

Efficient maintenance: accurate records and procedures to ensure efficiency

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

Testing, efficient procedures to enable component longevity, recommendations

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Calculate the parameters of pneumatic and hydraulic systems		**D1** Produce a presentation analysing fluid viscosity using Stokes' Law and validate how this relates to Navier–Stokes equations
P1 Determine the change in volume and pressure in pneumatic systems P2 Determine the change in volume and pressure in hydraulic systems	**M1** Using Bernoulli's Equation, calculate values at stationary incompressible flow	
LO2 Identify the notation and symbols of pneumatic and hydraulic components		**D2** Stating any assumptions, compare the applications of practical hydraulic and pneumatic systems
P3 Identify the purpose of components on a given diagram **P4** Explain the use of logic functions used within circuits **P5** Illustrate the use of advanced functions and their effect on circuit performance	**M2** Assess the different factors that impact on actuator choice for a given application	
LO3 Examine the applications of pneumatic and hydraulic systems		**D3** Evaluate the design modifications that can be introduced to improve the functionality and maintenance of pneumatic and hydraulic systems without creating reliability issues
P6 Investigate and analyse the design and function of a simple hydraulic or pneumatic system in a production environment **P7** Define the purpose and function of electrical control elements in a given hydraulic or pneumatic system	**M3** Justify the measures taken to improve circuit design in respect of performance	

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

Recommended Resources

Textbooks

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

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

STACEY, C. (1997) *Practical Pneumatics*. Oxford: Newnes.

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

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 16: Mechanical Principles

Unit 20: Automation, Robotics and Programmable Logic Controllers (PLCs)

Unit code	**K/615/1489**
Unit level	**4**
Credit value	**15**

Introduction

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

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

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

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

**this unit is the same as Unit 15: Automation, Robotics and Programmable Logic Controllers (PLCs) from Pearson BTEC Higher Nationals in Engineering*

Learning Outcomes

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

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

Essential Content

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

System operational characteristics:

Modular, unitary and rack mounted systems

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

Input and output devices (digital, analogue)

Interface requirements

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

Internal architecture

Different types of programming languages (IEC 61131-3)

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

Programming language:

Signal types

Number systems (binary, octal, hexadecimal)

Allocation lists of inputs and outputs

Communication techniques

Network methods

Logic functions (AND, OR, XOR)

Associated elements (timers, counters, latches)

Test and debug methods:

Systematic testing and debugging methods

Proper application of appropriate testing and debugging methods

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

Element considerations:

Types of robots

Mobile robotics

Tools and end effectors

Programming methods

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

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

Safety:

Cell safety features

Operating envelope

Operational modes

User interfaces

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Describe the design and operational characteristics of a PLC system		**D1** Analyse the internal architecture of a typical PLC to determine its operational applications
P1 Describe the key differences of PLC construction styles and their typical applications **P2** Determine the types of PLC input and output devices available **P3** Describe the different types of communication links used with PLCs	**M1** Explain the different types of PLC programming languages available	
LO2 Design a simple PLC program by considering PLC information, programming and communication techniques		**D2** Produce all elements of a PLC program for a given industrial task and analyse its performance
P4 Design and describe the design elements that have to be considered in the preparation of a PLC programme program **P5** Explain how communication connections are correctly used with the PLC	**M2** Examine the methods used for testing and debugging the hardware and software	
LO3 Describe the key elements of industrial robots and be able to program them with straightforward commands to perform a given task		**D3** Design and produce a robot program for a given industrial task
P6 Describe the types of industrial robots and their uses in industry **P7** Describe the types of robot end effectors available and their applications	**M3** Investigate a given industrial robotic system and make recommendations for improvement	

Pass	Merit	Distinction
LO4 Investigate the design and safe operation of a robot within an industrial application		**D4** Design a safe working plan for an industrial robotic cell in a given production process to include a full risk assessment
P8 Investigate the safety systems used within an industrial robotic cell	**M4** Analyse how the systems in place ensure safe operation of a given industrial robotic cell	

Recommended Resources

Textbooks

BOLTON, W. (2015) *Programmable Logic Controllers*. 5th ed. London: Elsevier.

DAWKINS, N. (ed.) (2014) *Automation and Controls: A Guide to Automation, Controls, PLCs and PLC Programming*. Seattle, Washington: Amazon Publishing.

PEREZ ANDROVER, E. (2012) *Introduction to PLCs: A Beginner's Guide to Programmable Logic Controllers*. Seattle, Washington: Amazon Publishing.

Websites

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

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 12: Traction and Rolling Stock

Unit 19: Electro, Pneumatic and Hydraulic Systems

Unit 23: Electrical and Electronic Principles

Unit 24: Digital Principles

Unit 25: Electronic Circuits and Devices

Unit 27: Programming

Unit 30: Computer Systems Architecture

Unit 21: Instrumentation and Control Systems

Unit **D/615/1490**

Unit level **4**

Credit value **15**

Introduction

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

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

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

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

**This unit is the same as Unit 20 Instrumentation and Control Systems from Pearson BTEC Higher Nationals in General Engineering*

Learning Outcomes

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

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

Essential Content

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

Instrumentation systems:

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

Instrumentation signal terminology:

The importance of instrumentation signal terminology, including accuracy, error, drift, repeatability, reliability, linearity, sensitivity, resolution, range and hysteresis

Signal conversion and conditioning:

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

LO2 **Investigate process control systems and controllers**

Process control systems:

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

Process controller terminology:

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

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

System terminology and concepts:

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

System tuning techniques:

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

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

Predicted values:

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

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Identify the instrumentation systems and devices used in process control		**D1** Critically review the industrial application of an instrumentation and control process system, using research evidence
P1 Define the types of sensor and transducers used in process control **P2** Describe how the sensors and transducers function **P3** Define the signal terminology used in process control **P4** Explain the different methods and standards used in signal conversion and conditioning	**M1** Explore industrial applications for sensors and transducers **M2** Analyse the accuracy of the sensors and transducers used in a particular application	
LO2 Investigate process control systems and controllers		**D2** Develop a recommendation for improvement to process control systems and controllers
P5 Describe the importance of process control systems **P6** Define the process controller terminology used in industrial applications	**M3** Explain a typical industrial application for a process control system	
LO3 Analyse the control concepts used within a process		**D3** Analyse the effectiveness of the control concepts used within a given process and suggest improvements
P7 Define the control terminology and concepts used in process control systems **P8** Describe the system tuning methods and techniques employed to improve performance	**M4** Explain the control terminology, concepts and tuning techniques used in a typical industrial application	
LO4 Apply predicted values to ensure stability within a control system		**D4** Discuss why the system responds in a certain way as the signals are applied
P9 Demonstrate the correct use of an instrumentation and control virtual simulation	**M5** Show how the virtual control system responds to a range of signal inputs	

Recommended Resources

Textbooks

BOLTON, W. (2015) *Instrumentation and Control Systems*. 2nd ed. Oxford: Newnes.

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

NISE, N.S. (2011) *Control Systems Engineering*. 6th ed. New Jersey: John Wiley & Sons.

Links

This unit links to the following related units:

Unit 1: Engineering Design

Unit 3: Engineering Science

Unit 25: Electronic Circuits and Devices

Unit 29: Strategic Information Systems

Unit 22: Quality and Process Improvement

Unit code H/615/1491

Unit level 4

Credit value 15

Introduction

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

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

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

**This unit is the same as Unit 17: Quality and Process Improvement from Pearson BTEC Higher Nationals in Engineering*

Learning Outcomes

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

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

Essential Content

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

Quality control:

The tools and techniques used to support quality control

Attributes and variables

Testing processes

Quality tools and techniques, including SPC

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

LO2 **Analyse cost effective quality control tools**

Quality costing:

Costing modules

The importance of qualifying the costs related to quality

How costs can be used to improve business performance

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

Standards for efficiency:

The history of standards

The role of standards and their importance in enabling and supporting trade and industry

Standards for measurement

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

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

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

Overview and function of quality:

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

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

Understanding and implementation of Six Sigma

Learning Outcomes and Assessment Criteria

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

Pass	Merit	Distinction
LO4 Analyse the importance of Total Quality Management and continuous improvement in manufacturing and service environments		**D4** Analyse how the appropriate application of Total Quality Management and continuous improvement in tools and techniques affect quality performance in the manufacturing and service environments
P6 Analyse the principles, tools and techniques of Total Quality Management and continuous improvement **P7** Analyse how the concept of Total Quality Management and continuous improvement could help in delivering high quality performance within businesses	**M4** Discuss how the appropriate application of Total Quality Management and continuous improvement in tools and techniques affect quality performance in the manufacturing and service environments	

Recommended Resources

Textbooks

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

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

Links

This unit links to the following related units:

Unit 5: Railway Operations

Unit 18: Engineering Management

Unit 23: Electrical and Electronic Principles

Unit code	**M/615/1493**
Unit level	**4**
Credit value	**15**

Introduction

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

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

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

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

Learning Outcomes

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

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

Essential Content

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

Fundamental electrical quantities and concepts:

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

Circuit laws:

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

Kirchhoff's and Thevenin's laws; superposition

Energy and power:

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

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

Fundamental quantities of periodic waveforms:

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

Mathematical techniques:

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

Reactive components:

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

Circuits with sinusoidal sources:

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

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

Ideal transformer and rectification:

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

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

Semiconductor material:

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

Simple semiconductor devices:

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

Simple semiconductor applications:

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

Transistors: switches and signal amplifiers

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

Analogue concepts:

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

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

Digital concepts:

Logic circuits implemented with switches or relays

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

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

Truth Tables

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Apply an understanding of fundamental electrical quantities to analyse circuits with constant voltages and currents</td><td rowspan="2">D1 Evaluate the operation of a range of circuits with constant sources, using relevant circuit theories.</td></tr>
<tr><td>P1 Apply the principles of circuit theory to simple circuits with constant sources, to explain the operation of that circuit</td><td>M1 Apply the principles of circuit theory to a range of circuits with constant sources, to explain the operation of that circuit</td></tr>
<tr><td colspan="2">LO2 Analyse circuits with sinusoidal voltages and currents</td><td rowspan="2">D2 Analyse the operation and behaviour of series and parallel RLC circuits, including resonance and using the principles of circuit theory with sinusoidal sources.</td></tr>
<tr><td>P2 Analyse series RLC circuits, using the principles of circuit theory with sinusoidal sources.</td><td>M2 Analyse series and parallel RLC circuits, using the principles of circuit theory with sinusoidal sources.</td></tr>
<tr><td colspan="2">LO3 Describe the basis of semiconductor action, and its application to simple electronic devices</td><td rowspan="2">D3 Analyse the performance of a range of discrete semiconductor devices in terms of simple semiconductor theory, and suggest applications for each.</td></tr>
<tr><td>P3 Describe the behaviour of a p-n junction in terms of semiconductor behaviour

P4 Demonstrate the action of a range of semiconductor devices</td><td>M3 Explain the operation of a range of discrete semiconductor devices in terms of simple semiconductor theory</td></tr>
</table>

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

Recommended Resources

Textbooks

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

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

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

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

Links

This unit links to the following related units:

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 17: Materials Properties and Testing

Unit 24: Digital Principles

Unit 25: Electronic Circuits and Devices

Unit 24: Digital Principles

Unit code T/615/1494

Unit level 4

Credit value 15

Introduction

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

The unit introduces 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 are 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.

**This unit is the same unit as Unit 20: Digital Principles in the Pearson BTEC Higher Nationals in Engineering*

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
LO1 Explain and analyse simple combinational logic circuits		**D1** Analyse, optimise and enhance combinational logic circuits, making best use of Truth Table, Boolean Algebra and Karnaugh Map
P1 Explain and analyse the operation of a simple combinational logic circuit, making limited use of Truth Table, Boolean Algebra and Karnaugh Map	**M1** Analyse and optimise the operation of a combinational logic circuit making good use of Truth Table, Boolean Algebra and Karnaugh Map	
LO2 Explain and analyse simple sequential logic circuits		**D2** Analyse, optimise and enhance a sequential logic circuit, making use of Timing Diagrams
P2 Explain and analyse the operation of a simple sequential logic circuit, making use of Timing Diagrams	**M2** Analyse and optimise a simple sequential logic circuit, making use of Timing Diagrams	
LO3 Describe and evaluate the technologies used to implement digital electronic circuits		**D3** Apply lab equipment to configure, test and evaluate digital circuits, comparing and evaluating characteristics of different technologies
P3 Apply lab equipment to describe and evaluate simple digital circuits	**M3** Apply lab equipment to configure and test simple digital circuits	
LO4 Describe and analyse a range of digital subsystems, hence establishing the building blocks for larger systems		**D4** 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
P4 Describe and analyse the principles of a range of different logic subsystems	**M4** 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*. Harlow: Pearson.

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

Links

This unit links to the following related units:

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 23: Electrical and Electronic Principles

Unit 25: Electronic Circuits and Devices

Unit 25: Electronic Circuits and Devices

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

Introduction

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

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

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

**This unit is the same unit as Unit 22: Electronic Circuits and Devices in the Pearson BTEC Higher Nationals in Engineering*

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
LO1 Determine the operational characteristics of amplifier circuits		**D1** Assess the results obtained from the application of practical and virtual tests on amplifier circuits studied
P1 Describe the types of amplifiers available and their applications **P2** Examine the different performance characteristics of types of amplifier	**M1** Explain the results obtained from applying practical tests on an amplifier's performance	
LO2 Investigate the types and effects of feedback on an amplifier's performance		**D2** Evaluate the results of practical and virtual tests to analyse the effect of feedback on an amplifier's performance
P3 Examine the types of feedback available and their effect on the amplifier's performance **P4** Describe a circuit which employs negative feedback	**M2** Perform practical tests to show the effect of feedback on an amplifier's performance	
LO3 Examine the operation and application of oscillators		**D3** Analyse the results obtained from applying practical and virtual tests on oscillators studied
P5 Examine types of available oscillators and their applications	**M3** Assess the performance characteristics of types of oscillators	
LO4 Apply testing procedures to electronic devices and circuits		**D4** Analyse and compare the results obtained from applying practical and virtual tests on devices and circuits studied
P6 Select suitable electronic devices and their parent circuits and identify the appropriate manufacturer's data sheets **P7** Interpret relevant information from manufacturer's data when testing electronic devices and circuits	**M4** 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. London: Pearson.

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

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

Websites

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

Links

This unit links to the following related units:

Unit 2: Engineering Maths

Unit 3: Engineering Science

Unit 17: Materials Properties and Testing

Unit 23: Electrical and Electronic Principles

Unit 24: Digital Principles

Unit 26: Management and Operations

Unit code	**D/508/0488**
Unit level	**4**
Credit value	**15**

Introduction

The aim of this unit is to help students understand the difference between the function of a manager and the role of a leader. Students will consider the characteristics, behaviours and traits which support effective management and leadership. In addition, this unit will introduce the concept of operations as both a function and a process which all organisations must adopt to conduct business. Students will be introduced to contemporary and historical theories and concepts which will support their learning for this unit.

On successful completion of this unit students will have developed sufficient knowledge and understanding of how management and operations make a positive, efficient and effective contribution to an organisation at a junior level. This could be in the role of a team leader or managing a specific aspect of an operation function and/or process.

Underpinning all aspects of the content for this unit you will consider topics under two broad headings: management and operations.

**This unit is the same unit as Unit 4: Management Operations in the Pearson BTEC Higher Nationals in Business*

Learning Outcomes

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

1. Differentiate between the role of a leader and the function of a manager.
2. Apply the role of a leader and the function of a manager in given contexts.
3. Demonstrate an appreciation of the role leaders and managers play in the operations function of an organisation.
4. Demonstrate an understanding of the relationship between leadership and management in a contemporary business environment.

Essential Content

LO1 **Differentiate between the role of a leader and the function of a manager**

Management theory:

Contemporary and seminal theories of management such as management by objectives, classical management theories, behavioural theory and contingency theory.

Leadership vs management:

The definitions and differences of both a leader and a manager.

Management functions such as planning, organising, controlling and directing.

Theories of leadership traits, style and contingency.

Transformational and Transactional Leadership.

Action Centred Leadership.

‘Hard’ management skills and ‘soft’ leadership skills.

LO2 **Apply the role of a leader and the function of a manager in given contexts**

How situations affect the role of a leader and function of a manager:

Situational leadership, systems leadership, task or relationship-orientated approaches.

The application of chaos theory and management by objectives.

LO3 **Demonstrate an appreciation of the role leaders and managers play in the operations function of an organisation**

Theories of operations and operations management:

Six sigma, lean production and queuing theory.

Different operations management approaches:

The use of different management approaches: Principles of Total Quality Management (TQM), Just-in-Time Inventory and the concept of continuous improvement (Kaizen)

Operational functions:

Control and Distribution Systems.

Transformation of raw material into finished goods/services.

Process design.

Capacity management.

Logistics and inventory management.

Scheduling.

LO4 **Demonstrate an understanding of the relationship between leadership and management in a contemporary business environment**

Different dimensions of contemporary business environment:

The relationship that leadership and management have in the context of corporate social responsibility; culture, values, ethics and sustainability.

The relationship with stakeholders and meeting stakeholder expectations in the context of encouraging, developing and sustaining entrepreneurship and intrapreneurship.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Differentiate between the role of a leader and the function of a manager</td><td rowspan="4">LO1 and LO2
D1 Critically analyse and evaluate the different theories and approaches to leadership in given contexts.</td></tr>
<tr><td>P1 Define and compare the different roles and characteristics of a leader and a manager.</td><td>M1 Analyse and differentiate between the role of a leader and function of a manager by effectively applying a range of theories and concepts.</td></tr>
<tr><td colspan="2">LO2 Apply the role of a leader and the function of a manager in given contexts</td></tr>
<tr><td>P2 Examine examples of how the role of a leader and the function of a manager apply in different situational contexts.
P3 Apply different theories and models of approach, including situational leadership, systems leadership and contingency.</td><td>M2 Assess the strengths and weaknesses of different approaches to situations within the work environment.</td></tr>
<tr><td colspan="2">LO3 Demonstrate an appreciation of the role leaders and managers play in the operations function of an organisation</td><td rowspan="4">LO3 and LO4
D2 Critically evaluate application of operations management and factors that impact on the wider business environment.</td></tr>
<tr><td>P4 Explain the key approaches to operations management and the role that leaders and managers play.
P5 Explain the importance and value of operations management in achieving business objectives.</td><td>M3 Evaluate how leaders and managers can improve efficiencies of operational management to successfully meet business objectives.</td></tr>
<tr><td colspan="2">LO4 Demonstrate an understanding of the relationship between leadership and management in a contemporary business environment</td></tr>
<tr><td>P6 Assess the factors within the business environment that impact upon operational management and decision-making by leaders and managers.</td><td>M4 Analyse how these different factors affect the business environment and wider community.</td></tr>
</table>

Recommended Resources

HILL, A and HILL, T. (2011) *Essential Operations Management.* London: Palgrave.

PETTINGER, R. (2007) *Introduction to Management.* 4th ed. London: Palgrave Macmillan.

SLACK, N., BRANDON-JONES, A. and JOHNSTON, R. (2013) *Operations Management.* 7th ed. Harlow: Pearson.

SCHEDLITZKI, D. and EDWARDS, G. (2014) Studying Leadership: Traditional and Critical Approaches. London: SAGE.

Links

This unit links to the following related units:

Unit 5: Railway Operations

Unit 18: Engineering Management

Unit 27: Programming

Unit code D/615/1618

Unit level 4

Credit value 15

Introduction

Programming involves describing processes and procedures which are derived from algorithms. The ability to program is what sets apart a developer and an end user. Typically the role of the developer is to instruct a device (such as a computer) to carry out instructions; the instructions are known as source code and is written in a language that is converted into something the device can understand. The device executes the instructions it is given.

Algorithms help to describe the solution to a problem or task; by identifying the data and the process needed to represent the problem or task *and* the set of steps needed to produce the desired result.

Programming languages typically provide the representation of both the data and the process; they provide control constructs and data types (which can be numbers, words, and objects, and be constant or variable).

The control constructs are used to represent the steps of an algorithm in a convenient yet unambiguous fashion. Algorithms require constructs that can perform sequential processing, selection for decision-making, and iteration for repetitive control. Any programming language that provides these basic features can be used for algorithm representation.

This unit introduces students to the core concepts of programming with an introduction to algorithms and the characteristics of programming paradigms.

Among the topics included in this unit are: introduction to algorithms, procedural, object-orientated & event-driven programming, security considerations, the integrated development environment and the debugging process.

On successful completion of this unit students will be able to design and implement algorithms in a chosen language within a suitable Integrated Development Environment (IDE). This IDE will be used to develop and help track any issues with the code.

As a result they will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation which are crucial for gaining employment and developing academic competence.

**This unit is the same unit as Unit 1: Programming in the Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

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

1. Define basic algorithms to carry out an operation and outline the process of programming an application.
2. Explain the characteristics of procedural, object-orientated and event-driven programming, conduct an analysis of a suitable Integrated Development Environment (IDE).
3. Implement basic algorithms in code using an IDE.
4. Determine the debugging process and explain the importance of a coding standard.

Essential Content

LO1 **Define basic algorithms to carry out an operation and outline the process of programming an application**

Algorithm definition:

Writing algorithms to carry out an operation, e.g. Bubble sort.

The relationship between algorithms and code.

The generation process of code; the roles of the pre-processor, compiler and linker, interpreter.

LO2 **Explain the characteristics of procedural, object-orientated and event-driven programming. Conduct an analysis of a suitable Integrated Development Environment (IDE)**

Characteristics of code:

Definitions of: data types (the role of constants/variables), methods (including input/output), control structures, iteration, scope, parameter passing, classes, inheritance and events.

Key components of an IDE with a brief explanation each component.

LO3 **Implement basic algorithms in code using an IDE**

Implementation:

Developing simple applications which implements basic algorithms covered in LO1, using the features of a suitable language and IDE. Consider possible security concerns and how these could be solved.

LO4 **Determine the debugging process and explain the importance of a coding standard**

Review and reflection:

Documentation of the debugging process in the IDE, with reference to watch lists, breakpoints and tracing.

How the debugging process can be used to help developers fix vulnerabilities, defects and bugs in their code.

What a coding standard is and its benefits when writing code.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Define basic algorithms to carry out an operation and outline the process of programming an application		
P1 Provide a definition of what an algorithm is and outline the process in building an application.	**M1** Determine the steps taken from writing code to execution.	**D1** Examine the implementation of an algorithm in a suitable language. Evaluate the relationship between the written algorithm and the code variant.
LO2 Explain the characteristics of procedural, object-orientated and event-driven programming, conduct an analysis of a suitable Integrated Development Environment (IDE)		
P2 Give explanations of what procedural, object-orientated and event-driven paradigms are; their characteristics and the relationship between them.	**M2** Analyse the common features that a developer has access to in an IDE.	**D2** Critically evaluate the source code of an application which implements the programming paradigms, in terms of the code structure and characteristics.
LO3 Implement basic algorithms in code using an IDE		
P3 Write a program that implements an algorithm using an IDE.	**M3** Use the IDE to manage the development process of the program.	**D3** Evaluate the use of an IDE for development of applications contrasted with not using an IDE.
LO4 Determine the debugging process and explain the importance of a coding standard		
P4 Explain the debugging process and explain the debugging facilities available in the IDE. **P5** Outline the coding standard you have used in your code.	**M4** Evaluate how the debugging process can be used to help develop more secure, robust applications.	**D4** Critically evaluate why a coding standard is necessary in a team as well as for the individual.

Recommended Resources

This unit does not specify which programme language should be used to deliver this content – this decision can be made by the tutor.

Examples of languages that are used in industry are C#, Python, Ruby, Java, but any language which will allow the student to achieve the Learning Outcomes is acceptable.

Textbooks

AHO, A. V. et al. (1987) *Data Structures and Algorithms*. 1st ed. Boston: Addison-Wesley.

HUNT, A. et al. (2000) *The Pragmatic Programmer: From Journeyman to Master.* 1st ed. Boston: Addison-Wesley.

MCCONNELL, S. (2004) Code Complete: A Practical Handbook of Software Construction. 2nd ed. Harlow: Microsoft Press.

Links

This unit links to the following related units:

Unit 28: Networking

Unit 29: Strategic Information Systems

Unit 30: Computer Systems Architecture

Unit 28: Networking

Unit code H/615/1619

Unit level 4

Credit value 15

Introduction

Computer networks are the driving force behind the evolution of computer systems and allow users to access data, hardware and services regardless of their location. Being knowledgeable about the underlying principles of networking is of vital importance to all IT professionals. Networking is an environment that is increasingly complex and under continuous development.

Complex computer networking has connected the world by groups of small networks through internet links to support global communications. It supports access to digital information anytime, anywhere using many applications like e-mail, audio and video transmission, including the World Wide Web, and this has opened the floodgates to the availability of information.

The aim of this unit is to provide students with wider background knowledge of computer networking essentials, how they operate, protocols, standards, security considerations and the prototypes associated with a range of networking technologies.

Students will explore a range of hardware, with related software, and will configure and install these to gain knowledge of networking systems. A range of networking technologies will be explored to deliver a fundamental knowledge of Local Area Networking (LAN), Wide Area Networking (WAN) and their evolution to form large-scale networks and the protocol methodologies related to IP data networks will be explored.

On successful completion of this unit students will gain knowledge and skills to successfully install, operate and troubleshoot a small network; and the operation of IP data networks, router, switching technologies, IP routing technologies, IP services and basic troubleshooting. Supporting a range of units in the Higher National suite, this unit underpins the principles of networks for all and enables students to work towards their studies in vendor units, if applicable.

Students will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation, which are crucial for gaining employment and developing academic competence.

**This unit is the same unit as Unit 2: Networking in the Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

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

1. Examine networking principles and their protocols.
2. Explain networking devices and operations.
3. Design efficient networked systems.
4. Implement and diagnose networked systems.

Essential Content

LO1 **Examine networking principles and their protocols**

Role of networks:

Purpose, benefits, resource implications, communications, working practice, commercial opportunity, information sharing, collaboration.

System types:

Peer-based, client-server, cloud, cluster, centralised, virtualised.

Networking standards:

Conceptual models e.g. OSI model, TCP/IP model; standards: e.g. IEEE 802.x.

Topology:

Logical e.g. Ethernet, Token Ring; physical e.g. star, ring, bus, mesh, tree, ring.

Protocols:

Purpose of protocols; routed protocols e.g. IPv4, IPv6, IPv6 addressing, Global unicast, Multicast, Link local, Unique local, EUI 64, Auto configuration, FTP, HTTP, SMTP, POP3, SSL; management of protocols for addressing.

LO2 **Explain networking devices and operations**

Networking devices:

Servers; hub, routers; switches; multilayer switch, firewall, HIDS, repeaters; bridges; wireless devices; access point (wireless/wired), content filter, Load balancer, Modem, Packet shaper, VPN concentrator.

Networking software:

Client software, server software, client operating system, server operating system, Firewall.

Server type:

Web, file, database, combination, virtualisation, terminal services server.

Server selection:

Cost, purpose, operating system requirement.

Workstation:

Hardware e.g. network card, cabling; permissions; system bus; local-system architecture e.g. memory, processor, I/O devices.

LO3 **Design efficient networked systems**

Bandwidth:

Expected average load; anticipated peak load; local internet availability; cost constraints, throughput.

Users:

Quality expectations, concept of system growth.

Networking services and applications:

DHCP; static vs dynamic IP addressing, reservations, scopes, leases, options (DNS servers, Suffixes), IP helper, DHCP relay, DNS records, Dynamic DNS.

Communications:

Suited to devices, suited to users, supportive of lifestyle desires, supportive of commercial requirements, security requirements, quality of service needs.

Scalable:

Able to support device growth, able to support addition of communication devices, able to cope with bandwidth use and trend changes, protocol utilisation, addressing.

Selection of components:

Supporting infrastructure needs; supporting connectivity requirements.

LO4 **Implement and diagnose networked systems**

Devices:

Installation of communication devices, allocation of addresses, local client configuration, server configuration, server installation, security considerations.

Verification of configuration and connectivity:

Installation of internet work communication medium, ping, extended ping, traceroute, telnet, SSH.

System monitoring:

Utilisation, bandwidth needs, monitoring user productivity and security of the system.

Maintenance schedule:

Backups, upgrades, security, auditing.

Diagnose and resolve layer 1 problems:

Framing, CRC, Runts, Giants, Dropped packets, late collisions, Input/Output errors.

Policy review:

Bandwidth, resource availability.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Examine networking principles and their protocols</td><td rowspan="4">LO1 and LO2
D1 Considering a given scenario, identify the topology protocol selected for the efficient utilisation of a networking system.</td></tr>
<tr><td>P1 Discuss the benefits and constraints of different network types and standards.
P2 Explain the impact of network topology, communication and bandwidth requirements.</td><td>M1 Compare common networking principles and how protocols enable the effectiveness of networked systems.</td></tr>
<tr><td colspan="2">LO2 Explain networking devices and operations</td></tr>
<tr><td>P3 Discuss the operating principles of networking devices and server types.
P4 Discuss the inter-dependence of workstation hardware with relevant networking software.</td><td>M2 Explore a range of server types and justify the selection of a server, considering a given scenario regarding cost and performance optimisation.</td></tr>
<tr><td colspan="2">LO3 Design efficient networked systems</td><td rowspan="2">D2 Design a maintenance schedule to support the networked system.</td></tr>
<tr><td>P5 Design a networked system to meet a given specification.
P6 Test and evaluate the design to meet the requirements and analyse user feedback.</td><td>M3 Install and configure network services and applications on your choice.</td></tr>
<tr><td colspan="2">LO4 Implement and diagnose networked systems</td><td rowspan="2">D3 Use critical reflection to evaluate own work and justify valid conclusions.</td></tr>
<tr><td>P7 Implement a networked system based on a prepared design.
P8 Document and analyse test results against expected results.</td><td>M4 Recommend potential enhancements for the networked systems.</td></tr>
</table>

Recommended Resources

Textbooks

Burgess, M. (2003) *Principles of Network and System Administration*. 2nd ed.
London: John Wiley and Sons Ltd.

Hallberg, B. (2005) *Networking: A Beginner's Guide*. 4th ed.
New York: Osborne/McGraw-Hill US.

Limoncelli, T. and Hogan, C. (2001) *The Practice of System and Network Administration*. Boston: Addison-Wesley.

Lowe, D. (2005) *Networking All-in-One Desk Reference for Dummies*. 2nd ed.
Hungry Minds Inc.

Olifer, N. and Olifer, V. (2005) *Computer Networks: Principles, Technologies and Protocols for Network Design*. London: John Wiley and Sons Ltd.

Stallings, W. (2003) *Data and Computer Communications*. 7th ed. New Jersey: Prentice Hall.

Subramanian, M. (2000) *Network Management: An Introduction to Principles and Practice*. Boston: Addison-Wesley.

Tanenbaum, A. (2002) *Computer Networks*. New Jersey: Prentice Hall PTR.

Links

This unit links to the following related units:

Unit 11: Railway Telecommunications

Unit 27: Programming

Unit 29: Strategic Information Systems

Unit 30: Computer Systems Architecture

Unit 29: Strategic Information Systems

Unit code A/615/1626

Unit level 4

Credit value 15

Introduction

Information is the most valuable resource that an organisation possesses. The effective gathering, protection, analysis, processing and dissemination of information is vital to the success of any organisation. As globalisation and the 24-hour economy develop and increase, organisations must ensure that their information systems are reliable, efficient and able to cope with rapid change.

This unit introduces students to the importance of information to organisations. It will examine how systems can be used to support core business functions and enable organisations to be more productive and competitive within the global marketplace.

Students will be required to analyse the information needs of an organisation at different levels and within different functional areas. It is important that computing professionals are able to understand how an organisation works and how it uses information in order to be able to design, implement, maintain and manage secure information systems to support its operations.

Among the topics included in this unit are understanding organisations in terms of their information needs and the variances within different functional areas. Examination of different information systems at the operational, tactical and strategic levels will be required, in addition to evaluating their effectiveness and role in terms of decision making and gaining competitive advantage.

On successful completion of this unit students will have an insight into the types of systems and technologies available for effective information processing. Critical analysis will also be used to examine the integrated role that each of these play in contributing to the efficiency and competitiveness of organisations.

As a result students will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation, which are crucial for gaining employment and developing academic competence.

**This unit is the same unit as Unit 7: Strategic Information Systems in the Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

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

1. Analyse the information requirements of organisations.
2. Discuss the types of information systems that are used within all levels of an organisation.
3. Demonstrate the use of an information system to produce management information.
4. Evaluate the effectiveness of strategic information systems.

Essential Content

LO1 **Analyse the information requirements of organisations**

Functional area information requirements:

Finance and accounts for payroll, pensions, supplier payments and invoicing etc., human resources e.g. employee records, personnel data, appraisals, CPD etc., stock control, sales, marketing, research and development, production, distribution, IT, customer service and administration.

Information needs:

How different functional areas use and process data effectively; the integration of data and information within an organisation.

Requirements analysis:

The inputs, outputs and processing activities; information distribution requirements e.g. by location, department, individual/customer.

LO2 **Discuss the types of information systems that are used within all levels of an organisation**

Information systems types:

Business information systems, decision support systems, management information systems, strategic/executive information systems, office information systems, transaction processing systems, expert systems, global information systems, data warehouse systems, enterprise systems, enterprise resource planning systems, integrated information systems.

Categories of information systems:

Operational, tactical and strategic information systems.

Information and data:

Definition of information and data, sources of information, information requirements and the needs for information at different levels within an organisation; storing information and its importance with regard to security, accuracy and relevance; outputs e.g. payroll, invoicing, ordering, bookings, stock control, personnel records, goods tracking, decision-making, marketing, customer service.

LO3 **Demonstrate the use of an information system to produce management information**

Management information:

Reports e.g. sales report, college enrolment statistics, marketing analysis (brick v click), trends in the market, competition and market share.

Gathering information:

Defining requirements; establishing sources of information; defining other factors to be considered e.g. constraints and access to information.

Selecting information:

Analysis of information in terms of validity, accuracy, currency and relevancy; identifying and rationalising meaningful information from data sets.

Uses:

Proficiency in terms of accessing quality information that can be used for decision-making, problem-solving, predictions, trending and forecasting.

LO4 **Evaluate the effectiveness of strategic information systems**

Models for strategic information systems:

Porters Competitive Advantage and Wiseman's Strategic Planning Process.

Competitive advantage:

How can competitive advantage be measured and attributed to the implementation of a strategic information system?

Gaining competitive advantage:

Delivering a differentiated product or service; delivering a product or service at a lower cost; specific segmentation of the market e.g. targeted marketing to specific target audiences; innovative product or service design and implementation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Analyse the information requirements of organisations		**D1** Evaluate the inputs, outputs and processing activities of a selected organisation.
P1 Discuss the information needs and requirements for the functional departments of an organisation. **P2** Produce an input/output (I/O) diagram to represent the data and information requirements of a functional department.	**M1** Compare and contrast different processing activities that occur within functional departments within an organisation.	
LO2 Discuss the types of information systems that are used within all levels of an organisation		**D2** Differentiate between the function and purpose of information systems at different levels within an organisation.
P3 Describe the function of different information systems. **P4** Discuss the information needs required at differing levels within an organisation.	**M2** Analyse the effectiveness of information systems at the operational, tactical and strategic levels within an organisation.	
LO3 Demonstrate the use of an information system to produce management information		**D3** Critique, with examples, how a given organisation can use information for effective decision-making and forecasting.
P5 Demonstrate the use of an information system for management reporting purposes. **P6** Discuss the importance of an organisation having data and information that is current, valid and accurate.	**M3** Analyse the constraints that an organisation can face when gathering data and information.	

Pass	Merit	Distinction
LO4 Evaluate the effectiveness of strategic information systems		**D4** Evaluate how strategic information systems can contribute to the competitiveness of organisations.
P7 Identify different models that can be applied to strategic information systems.	**M4** Justify the ways in which an organisation can obtain competitive advantage within a global market.	

Recommended Resources

Textbooks

Peppard, J. (2016) *The Strategic Management of Information Systems: Building a Digital Strategy*. 4th ed. New York: John Wiley & Sons.

Robson, W. (1997) *Strategic Management and Information Systems: An Integrated Approach*. 2nd ed. London: Prentice Hall.

Ward, J. (2002) *Strategic Planning for Information Systems*. 3rd ed. London: John Wiley & Sons.

Whitely, D. (2013) *An Introduction to Information Systems*. Oxford: Palgrave Macmillan.

Websites

it.toolbox.com	ToolBox.com Strategic Information System Toolbox (Wiki)
www.mbaknol.com	MBA Knowledge Base Strategic Information Systems (Article)

Links

This unit links to the following related units:

Unit 27: Programming

Unit 28: Networking

Unit 30: Computer Systems Architecture

Unit 30: Computer Systems Architecture

Unit code J/615/1628

Unit level 4

Credit value 15

Introduction

As technology develops, it is important to have a working foundation on which to build your knowledge. Despite hardware and software being constantly updated and seemingly becoming more complex, students with a solid, underpinned knowledge about computer systems architecture will not only be able to answer questions like, "How does a central processor work?", "What does an operating system do?", "How is information stored?", "What is an instruction set?" and "How do I actually connect to the internet?", but will also be able to transfer and apply their knowledge and skill to many other areas.

This unit introduces students to the foundations of computer systems architecture together with the integrated hardware and software components and subsystems that enable and allow data to be input, processed and output. The unit further explores the concepts of operating systems, hardware management and computer networks together with the practical skills needed to diagnose, troubleshoot and maintain computer systems taking the security of these systems into consideration.

Among the topics included in this unit are: CPUs, memory, input & output devices, ALU operations, program execution, operating systems (including kernel, file systems, API and system calls), hardware management, installation, firmware, device drivers, networking (including OSI and TCP/IP models), error and information gathering, fault diagnostics, security and problem resolution.

On successful completion of this unit, students will be able to explain the purpose and role of operating systems, the relationship between the subsystems embedded within a central processing unit, the core hardware and software components associated with computer operations and be able to configure the hardware and systems needed to establish a computer network together with practical diagnostic and troubleshooting techniques. As a result they will develop skills such as communication literacy, critical thinking, analysis, reasoning and interpretation which are crucial for gaining employment and developing academic competence.

**This unit is the same unit as Unit 8: Computer System Architecture in the Pearson BTEC Higher Nationals in Computing*

Learning Outcomes

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

1. Explain the relationships between hardware components and the subsystems used in a computer system.
2. Categorise the key features and services provided by different computer operating systems and hardware.
3. Use network communication technology and the associated services to connect computer systems.
4. Demonstrate diagnostic and troubleshooting skills to solve hardware, software and networking related issues.

Essential Content

LO1 **Explain the relationships between hardware components and the subsystems used in a computer system**

Hardware components and subsystems:

Computers consist of four main subsystems (Von Neumann Architecture, Memory, CPU (Arithmetical & Logic Unit (ALU) and Control Unit), Input and output Systems).

Review Memory subsystems regarding programs and data (variable) storage (ROM, RAM, size, speed, operation and structure).

Explore Input/output systems and structure (communicating with other devices (screen, keyboard, printers, etc.), storage (Hard Disk Drives (HDD), DVD's, etc.), IO controllers & data transfer (speed, buffers, interrupts, etc.).

Discuss ALU subsystems (mathematical & logical operations, registers, bus, etc.).

Investigate how the Control Unit works (program code & language, fetch, decode, execute, halt) including an introduction to machine language instructions (reduced instruction and complex instruction sets: arithmetic, compare, branch, control, Program Counter (PC), Instruction Register (IR) and Instruction decoder.

LO2 **Categorise the key features and services provided by different computer operating systems and hardware**

Operating system types and hardware:

Introduce different operating systems and types (desktop & server/network, mobile, embedded systems (e.g. Windows 10, Windows Server 2012/2016, Linux, Unix, MacOS, IOS, Android, etc.).

Hardware management and connections including the hardware abstraction layer, firmware and device drivers (network cards, video cards, optical drives, magnetic disks, solid state drives, RAID, etc.).

Installing and configuring common peripheral devices (mouse, keyboard, scanners, biometrics, webcams, smartcards, motion sensor, printers, speakers, display devices, etc.).

Features and services:

Introduce Operating Systems Architecture (Kernel, File Systems, API).

Review how operating systems function and provide services (user interface, memory management (Direct Memory Access), file management).

LO3 **Use network communication technology and the associated services to connect computer systems**

Networking technology and services:

Introduction to network protocols (HTTP, SMTP, TCP, UDP, etc.) including the OSI and TCP/IP models.

Hardware and network addresses (physical/MAC addresses, logical/IP addresses).

Network devices and components (network interface cards (NIC), network cables, switches, wireless access points, routers, network services).

Connecting computer systems to a network:

Introduce topologies including physical and logical: bus, star (extended star), ring and mesh.

Establishing network connections including wired/wireless client configuration.

Security of networking systems and the importance of this.

LO4 **Demonstrate diagnostic and troubleshooting skills to solve hardware, software and networking related issues.**

Hardware, software & networking issues and maintenance:

Different hardware and software related problems and the implication of choices with regards to system administration, impact on users and business operations.

Explore methods of maintenance with regard to hardware and software. Diagnostic and troubleshooting skills:

Discuss information gathering methods and techniques (such as: system documents, user information, error codes, error messages, failure domain, problem history, etc.).

Consider solutions to security problems.

Analyse evidence and establish possible problem domains, complexity, priority and impact; introduce 'Research, Determine, Implement, Review, Document (and Repeat)'.

Creating and updating system documentation.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explain the relationships between hardware components and the subsystems used in a computer system		**LO1 and LO2** **D1** Evaluate the structure and functions of an operating system including memory, processor, device, file, security, performance and error management with regards to functionality, operation and dependency.
P1 Identify the main subsystems of a computer and explain how they are organised and connected. **P2** Explain the purpose of the Central Processing Unit (CPU) and include details on its operation.	**M1** Review the operation of the CPU and assess its dependency and performance with regards to associated systems and subsystems.	
LO2 Categorise the key features and services provided by different computer operating systems and hardware		
P3 Describe a range of different operating systems including the purpose, use and hardware requirements of each. **P4** Discuss the key features associated with the architecture of an operating system.	**M2** Analyse the services provided by an operating system with regards to user interaction, memory management, file management and hardware support.	
LO3 Use network communication technology and the associated services to connect computer systems		**D2** Evaluate the OSI and TCP/IP models with regards to hierarchy, layers and services including information on the associated protocols and hardware.
P5 Explain the relationships between hardware and network addresses including their use with regards to networking devices and components. **P6** Setup, configure and document appropriate hardware and software systems to establish computer based network connectivity.	**M3** Compare common physical and logical networking topologies and explain the differences and purposes of each.	

Pass	Merit	Distinction
LO4 Demonstrate diagnostic and troubleshooting skills to solve hardware, software and networking related issues.		**D3** Assess any future improvements that may be required to ensure the continued effectiveness of a computer system.
P7 Use information gathering methods to assess, troubleshoot and document solutions to a number of different technical hardware, software and networking issues. **P8** Conduct and document a range of maintenance activities with regards to computer hardware and software.	**M4** Review different diagnostic and troubleshooting skills including data gathering methods and techniques.	

Recommended Resources

Textbooks

Docter, Q., Dulaney, E. and Skandier, T. (2015) *CompTIA A+ Complete Study Guide: Exams 220-901 and 220-902.* New York: John Wiley & Sons Inc.

Mueller, S. (2015) *Upgrading and Repairing PCs.* New York: Que Publishing.

Patterson, D. and Hennessy, J. (2013) *Computer Organization and Design*: The Hardware/Software Interface. New Jersey: Elsevier.

Links

This unit links to the following related units:

Unit 27: Programming

Unit 28: Networking

Unit 29: Strategic Information Systems

Unit 31: Construction Technology

Unit code Y/615/1388

Unit level 4

Credit value 15

Introduction

The basic principles of construction technology have not changed for hundreds of years. However, the materials and techniques used to achieve these basic principles are constantly evolving; to enable the construction industry to deliver better quality buildings. Scarcity of resources and the continuing demand of more sophisticated clients, end users and other stakeholder interests, are driving the construction industry to provide buildings which facilitate enhanced environmental and energy performance, and greater flexibility, in response to ever increasing financial, environmental, legal and economic constraints.

This unit will introduce the different technological concepts used to enable the construction of building elements; from substructure to completion, by understanding the different functional characteristics and design considerations to be borne in mind when selecting the most suitable technological solution.

Topics included in this unit are: substructure, superstructure, finishes, building services and infrastructure components. On successful completion of this unit a student will be able to analyse scenarios and select the most appropriate construction technology solution.

**This unit is the same unit as Unit 2: Construction Technology in the Pearson BTEC Higher Nationals in Construction*

Learning Outcomes

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

1. Explain the terminology used in construction technology
2. Describe the different techniques used to construct a range of substructures and superstructures, including their function and design selection criteria
3. Identify the different types of civil engineering/infrastructure technology used in support of buildings
4. Illustrate the supply and distribution of a range of building services and how they are accommodated within the building.

Essential Content

LO1 **Explain the terminology used in construction technology**

Types of construction activity:

Low, medium and high-rise buildings, domestic buildings, for example house, flats and other multi-occupancy buildings, commercial buildings, for example offices and shops, industrial buildings, for example, light industrial and warehouses.

Construction technology terminology:

Loadbearing and non-loadbearing, structural stability, movement and thermal expansion, durability, weather and moisture resistance, aesthetics, fire resistance, sound insulation, resistance to heat loss and thermal transmission, dimensional co-ordination and standardisation, sustainability and scarcity of availability, on-site and off-site construction, legal requirements, buildability, health and safety.

Construction information:

Drawings, specification, schedules, CAD, Building Information Modelling (BIM).

Sustainability:

Supply chain

Lifecycle

'Cradle-to-grave'

'Cradle-to-cradle'

Circular economies.

LO2 **Describe the different techniques used to construct a range of substructures and superstructures, including their function and design selection criteria**

Pre-design studies:

Desk-top, Site Reconnaissance, Direct Soil Investigation techniques.

Substructure functions and design considerations:

Different methods for gathering disturbed and undisturbed samples, influence of soil type on foundation design, including water and chemical content, potential loads, position of trees and the impact on foundations, economic considerations, legal considerations (health and safety work in excavations), building regulations, plant requirements.

Types of foundations:

Shallow and deep foundations, strip and deep strip foundations, pad foundations, raft foundations, piled foundations (replacement and displacement piles).

Types of superstructure:

Traditional construction, framed construction: steel, composite concrete and steel, timber.

Walls; roofs; structural frames; claddings; finishes; services.

Walls:

External walls: traditional cavity, timber frame, lightweight steel.

Cladding: panel systems, infill systems, composite panel systems, internal partition walls.

Roofs:

Pitched and flat roof systems, roof coverings.

Floors:

Ground floors, intermediate floors, floor finishes.

Staircases:

Timber, concrete, metal staircases, means of escape.

Finishes:

Ceiling, wall and floor finishes.

LO3 **Identify the different types of civil engineering/infrastructure technology used in support of buildings**

Site remediation and de-watering:

Contamination management: cut-off techniques, encapsulation.

Soil remediation: stone piling, vibro-compaction.

De-watering: permanent sheet piling, secant piling, grout injection freezing, temporary techniques, such as pumping, wells, electro-osmosis.

Substructure works:

Basement construction: steel sheet piling, concrete diaphragm walls, coffer dams, caissons, culverts.

Superstructure works:

Reinforced concrete work: formwork, reinforcement, fabrication, concrete, steel.

LO4 **Illustrate the supply and distribution of a range of building services and how they are accommodated within the building**

Primary service supply

Cold water

Gas

Electricity.

Services distribution

Hot and cold water

Single phase and 3-phase electricity

Air conditioning ductwork.

Services accommodation:

Raised access flooring

Suspended ceilings

Partitioning

Rising ducts.

Learning Outcomes and Assessment Criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">LO1 Explain the terminology used in construction technology</td><td rowspan="2">D1 Evaluate how the functional characteristics and design selection criteria impact on the eventual design solution</td></tr>
<tr><td>P1 Describe the differences between residential, commercial and industrial buildings

P2 Explain how the functional characteristics and design selection criteria are informed by proposed building use

P3 Discuss the ways in which sustainability can be promoted in building projects</td><td>M1 Apply the terminology used in construction technology to a given building construction project</td></tr>
<tr><td colspan="2">LO2 Describe the different techniques used to construct a range of substructures and superstructures, including their function and design selection criteria</td><td rowspan="4">LO2 and LO3

D2 Prepare a design report identifying superstructure, substructure and civil engineering structures necessary for a given building construction project</td></tr>
<tr><td>P4 Describe the pre-design studies carried out and types of information collected for a given construction site

P5 Explain the functional characteristics and design criteria for primary and secondary elements of a building substructure and superstructure</td><td>M2 Analyse how site conditions impact on the design of foundations

M3 Illustrate how the component parts of an element allow it to fulfil its function</td></tr>
<tr><td colspan="2">LO3 Identify the different types of civil engineering/infrastructure technology used in support of buildings</td></tr>
<tr><td>P6 Describe techniques used for remediating the site prior to construction commencing

P7 Describe the types of substructure works carried out by civil engineers</td><td>M4 Compare different types of structural frame used to carry the primary and secondary elements of the superstructure</td></tr>
</table>

Pass	Merit	Distinction
LO4 Illustrate the supply and distribution of a range of building services and how they are accommodated within the building		
P8 Describe the supply arrangements for primary services **P9** Explain the distribution arrangements for primary services	**M5** Demonstrate the elements of the superstructure used to facilitate the primary services	**D3** Appraise how the distribution of the primary services impact on the overall design of the building

Recommended Resources

Textbooks

BRYAN, T. (2010) *Construction Technology: Analysis and Choice*, Oxford: Blackwell.

CHARTLETT, A. and MAYBERY-THOMAS, C. (2013) *Fundamental Building Technology.* 3rd ed. Abingdon: Routledge.

CHUDLEY, R. et al. (2012) *Advanced Construction Technology*. 5th ed. Harlow: Pearson Education Limited.

CHUDLEY, R. and GRENNO, R. (2016) *Building Construction Handbook*. Abingdon: Routledge.

FLEMING, E. (2005) *Construction Technology: An Illustrated Introduction*. Oxford: Blackwell.

Links

This unit links to the following related units:

Unit 6: Track Design

Unit 31: Surveying, Measuring & Setting Out

Unit 32: Surveying, Measuring & Setting Out

Unit code H/615/1393

Unit level 4

Credit value 15

Introduction

Infrastructure and new buildings are essential requirements of modern life. In both construction and civil engineering there is a need to conduct initial surveys to assist the design team in establishing a clearly defined starting point. Once designed, the priority becomes to 'set out' the structures to the required accuracy to facilitate the construction process. Finally, 'as built' surveys are necessary to assist future maintenance and improvements to the built asset.

This unit explores the techniques used to set up controls and conduct topographic surveys. It also covers communication of results and methods of setting out structures.

On successful completion of this unit students will be able to set up and assess the accuracy of control points. From these or any other control points the students will be able to complete a topographic survey or set out a structure. The students will also be able analyse errors in setting out and surveying.

**This unit is the same unit as Unit 7: Surveying, Measuring & Setting Out in the Pearson BTEC Higher Nationals in Construction*

Learning Outcomes

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

1. Undertake a survey to establish a station network for horizontal and vertical control
2. Explain the process of undertaking a topographic survey
3. Apply industry standard techniques in the production, transferring and staking out of co-ordinates of multiple construction elements
4. Prepare a report on the causes of errors and techniques to improve accuracy, including the use of digital data.

Essential Content

LO1 **Undertake a survey to establish a station network for horizontal and vertical control**

Description of types of control points

Primary controls, first and second order

Secondary control

Different methods of marking control points

The use of local, national and grid control available

Conducting a closed traverse

Carrying out a full closed traverse survey for horizontal and vertical controls

Methods for checking accuracy of the traverse

Matching the control station accuracy to national standards or recommendations

Calculations to obtain corrected co-ordinates

LO2 **Explain the process of undertaking a topographic survey**

Purpose of a topographic survey

Links to initial control

Techniques to communicate a completed survey

Cut and fill information obtained from a survey

Methods of completing a topographic survey

Equipment to be used to capture topographic details

Use of free station and GPS to complete the survey

Coding systems for features to be surveyed

Data transfer techniques.

LO3 **Apply industry standard techniques in the production, transferring and staking out of co-ordinates of multiple construction elements**

Examples of construction elements.

Building outlines, centre lines of structural elements, boundary locations from national co-ordinates, road centre lines, drainage and hard landscape features.

Setting out techniques.

Holistic view of setting from the whole to the part.

Use of free station, reference lines, stake out, tie distances within a total station program.

Techniques to obtain setting out data, including data transfer.

Process of setting out structures and offsetting lines of structural elements.

Horizontal and vertical control of construction, both initially and as the work commences.

LO4 **Prepare a report on the causes of errors and techniques to improve accuracy, including the use of digital data**

Errors in surveying and setting out.

Instrumentation error: prism constants, reflector heights, atmospheric influences, calibration certification, free station errors, discrete setting out.

Human errors: alignment of levelling staffs and hand- or tripod-mounted prisms, physical setting out constraints.

Improvement of accuracy:

Use of technology to provide checking methods

Testing procedures for instrumentation to be used in setting out and surveying

Comparing accuracy of set out element to nationally recognised standards.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Undertake a survey to establish a station network for horizontal and vertical control		**LO1 and LO2**
P1 Describe the types of control networks that are available for surveying, including examples of local and national stations **P2** Carry-out a closed traverse survey of a network, including at least five stations **P3** Calculate corrected co-ordinates and heights for the stations and explain the stages used	**M1** Calculate and compare the accuracy achieved in a closed traverse survey	**D1** Assess the accuracy of a network in the production of a topographic survey
LO2 Explain the process of undertaking a topographic survey		
P4 Explain the process of conducting a topographic survey for a given plot of land, including initial control **P5** Describe, with examples, common coding systems and data exchange processes, including communicating final outcomes	**M2** Review the content of a topographic survey, including analysis of its suitability to assist the design team in completing the design	
LO3 Apply industry standard techniques in the production, transferring and staking out of co-ordinates of multiple construction elements		
P6 Extract and transfer the required data from a given project to a total station in order to allow setting out to commence **P7** Complete a full setting out operation on a given project by utilising a total station free station programme, including both horizontal and vertical control	**M3** Analyse the accuracy achieved from a setting out operation from tie distances recorded, total station stored data and another means	**D2** Analyse both the accuracy achieved and the techniques used during the practical exercise

Pass	Merit	Distinction
LO4 Prepare a report on the causes of errors and techniques to improve accuracy, including the use of digital data		**D3** Analyse the techniques used to improve accuracy, including the implication of setting out errors and the application of industry standard technology/software
P8 Prepare a report on the common causes of errors in both setting out and surveying **P9** Compare the accuracy of setting out data to national standards	**M4** Evaluate the causes of errors in surveying, setting out and data transfer	

Recommended Resources

Textbooks

IRVINE, W. and MACLENNAN, F. (2005) *Surveying for Construction*. 5th ed. London: McGraw-Hill.

SCHOFIELD, W. and BREACH, M. (2007) *Engineering Surveying*. 6th ed. Oxford: Elsevier.

SADGROVE, B.M. (2007) *Setting Out Procedures for the Modern Built Environment*. London: Ciria.

UREN, J. and PRICE, W. (2010) *Surveying for Engineers*. 5th ed. Basingstoke: Palgrave Macmillan.

Websites

ice.org.uk	Institution of Civil Engineers (General Reference)
tsa-uk.org.uk	The Survey Association (General Reference)

Links

This unit links to the following related units:

Unit 6: Track Design

Unit 31: Construction Technology

11 Appendices

Appendix 1: Pearson BTEC Level 4 HNC in Rail Engineering Mapped to the Apprenticeship Standard Level 4 Rail Engineering Advanced Technician

	Knowledge								Behaviours								Skills							
Unit	K1	K2	K3	K4	K5	K6	K7	K8	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2	S3	S4	S5	S6	S7	S8
1	•	•	•	•					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
2		•								•	•								•	•				
3	•	•								•	•								•	•	•			
4	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
6	•	•	•		•	•			•	•	•	•	•	•		•	•	•	•	•	•	•	•	•
7	•	•	•		•		•			•	•	•	•	•		•	•	•	•		•	•	•	•
8	•	•			•					•	•	•	•	•		•	•	•	•		•			
9	•	•	•		•	•				•	•	•	•	•		•	•	•	•		•	•	•	•
10	•	•			•			•		•	•	•		•		•			•		•	•		•
11	•	•	•		•				•	•	•	•	•	•		•	•	•	•		•	•	•	•
12	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
13	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
14	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•
15	•	•	•							•	•	•	•	•		•	•	•	•		•	•		
16	•	•	•							•	•								•		•			
17	•	•	•							•	•	•					•	•	•	•	•			
18	•	•	•	•		•			•	•	•	•	•	•	•	•	•	•	•		•	•	•	•
19	•	•	•							•		•	•	•			•	•	•		•			
20	•	•	•							•		•	•	•	•	•	•	•	•	•	•	•	•	•

	Knowledge								Behaviours								Skills							
Unit	K1	K2	K3	K4	K5	K6	K7	K8	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2	S3	S4	S5	S6	S7	S8
21	•	•	•							•		•	•	•		•	•	•	•		•			•
22	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
23		•								•	•								•		•			
24		•								•	•								•		•			
25	•	•								•		•	•	•		•			•		•			
26			•	•	•	•			•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
27	•	•	•							•	•	•	•	•		•			•	•	•			
28		•	•			•	•			•	•	•	•	•		•		•	•		•	•	•	
29		•	•	•		•	•		•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
30		•	•			•			•	•	•	•	•	•	•	•		•	•		•	•	•	•
31	•	•	•	•		•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
32	•	•	•	•					•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Knowledge	
K1	Safe and Professional working practices including legislation, regulation, industry procedures, safety requirements, risk management and environmental impact
K2	The scientific, technical, engineering, mathematical and design principles (some of them complex) that are required in undertaking and directing maintenance, renewal and construction of and across The Railway.
K3	How to work effectively to design and develop engineering solutions and innovation including understanding of failure modes and their causes; advanced problem solving, diagnostic systems and development of preventative maintenance; asset management and whole life asset costs.
K4	How to deliver engineering solutions effectively including project management principles and systems to manage, time, resource, asset and quality management and assurance systems; business improvement and innovation systems, processes and techniques.
K5	How the Railway works as a system and their role within it. The critical interfaces across the Railway system and how those interfaces are managed
K6	The importance of 3rd party and internal business requirements and operational interfaces. The need for and understanding of client confidentiality and compliance with corporate policies including ethics, equality and diversity and sustainability.
K7	How the Railway works commercially including contractual principles and financial systems, forecasts and budgets, and performance implications and performance management techniques.
K8	How the Railway is evolving. Awareness and understanding of new technological developments across the Railway and how these will impact the future operation of The Railway.

Skills	
S1	Keep themselves and others safe by leading and demonstrating safe working practices. Understand, reinforce and comply with statutory regulations and organisational safety requirements, including competence and safe access to work locations.
S2	Produce a work plan based on safe systems of work that is informed by technical drawings, schematics and programmes of work needed for the development of rail engineering activity. Prepare contingency arrangements to manage change and risk as appropriate.
S3	Undertake and direct a high standard of technical work. Take responsibility for the efficient and effective delivery of technical work activities and projects. Undertake and supervise the operation of equipment & systems. Complete integrity & compliance checks on own work and that of others and ensure appropriate testing is undertaken. Transfer responsibility of assets once work has been completed. Be responsible and accountable for their own work and that of others.
S4	Solve problems: Design and develop a structured and/or innovative approach to problem solving and diagnosis. Apply appropriate methods and business improvement techniques. Predict and prevent failures through the analysis of data and the ability to provide feedback on these.
S5	Make informed and considered decisions and complex critical judgements as appropriate.
S6	Supervise and manage resources including the efficient utilisation of individuals, teams, tools, materials and equipment. Monitor and manage individual and team performance and development.
S7	Work collaboratively maintaining effective relationships with colleagues, clients, suppliers and the public. Support the development of others through coaching and mentoring.
S8	Communicate effectively across all management levels. Use oral, written, electronic and IT based methods and systems for the accurate communication, technical reporting & recording of information and management reporting.

Behaviours	
B1	Act professionally demonstrating dependability, determination, resilience, honesty and integrity. Respect others, act ethically and contribute to sustainable development.
B2	Proactively identify and manage risk so as to reduce this through planning, systematic monitoring and checking of information/feedback and management of changing circumstances on activity.
B3	Promote and exhibit a self-disciplined, self-motivated, proactive approach to work, able to make independent decisions whilst knowing one's limitations and when to ask for help or to escalate.
B4	Work reliably and safely to approved industry standards and safe working practices and ensuring others do likewise.
B5	Work effectively and collaboratively, individually and as part of a team, being aware of their actions and the impact they may have on others, maintaining effective relationships with colleagues, clients, suppliers and the public. Accept, allocate and supervise technical and other tasks.
B6	Receptive to giving and receiving constructive feedback, willing to learn new skills and adjust to change. Identifying, carrying out and recording CPD necessary to maintain and enhance competence.
B7	Demonstrate leadership, motivating and leading by example. Promote a culture of continuous improvement. Research and stay abreast of the educational, technological, social, political, and economic developments that can affect the industry.
B8	Prepared to make a personal commitment to their employer, the industry and its professional standards.

Appendix 2: Pearson BTEC Level 4 Higher National Certificate in Rail 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
2	x	x		x	x	x			x	x				
3	x	x		x	x	x			x	x				
4	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6	x	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				x	x			
9	x	x	x	x	x	x		x		x	x			
10	x	x	x	x	x	x		x		x	x			x
11	x	x	x	x	x	x		x		x	x			x
12	x	x	x	x	x	x	x	x		x	x			
13	x	x	x	x	x	x	x	x	x	x	x	x	x	x
14	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
15	**x**	**x**	**x**		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		
16	**x**						**x**	**x**	**x**	**x**	**x**			
17	**x**	**x**		**x**	**x**	**x**			**x**	**x**				
18	**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**			
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**		
24	**x**	**x**	**x**		**x**	**x**		**x**	**x**	**x**	**x**			
25	**x**	**x**	**x**		**x**	**x**		**x**	**x**	**x**	**x**			
26				**x**	**x**			**x**	**x**	**x**	**x**			
27	**x**	**x**	**x**		**x**		**x**	**x**	**x**		**x**			
28	**x**	**x**	**x**		**x**		**x**	**x**	**x**	**x**	**x**			**x**
29	**x**	**x**	**x**		**x**	**x**		**x**	**x**	**x**	**x**			
30	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**			
31		**x**		**x**			**x**			**x**	**x**			
32		**x**	**x**	**x**		**x**	**x**			**x**				

Appendix 3: Glossary of command verbs used for internally assessed units

This is a summary of the key terms used to define the requirements within units.

Term	Definition
Analyse	Present the outcome of methodical and detailed examination either: • breaking down a theme, topic or situation in order to interpret and study the interrelationships between the parts; and/or • of information or data to interpret and study key trends and interrelationships. Analysis can be through activity, practice, written or verbal presentation.
Apply	Put into operation or use. Use relevant skills/knowledge/understanding appropriate to context.
Arrange	Organise or make plans.
Assess	Offer a reasoned judgement of the standard/quality of a situation or a skill informed by relevant facts.
Calculate	Generate a numerical answer with workings shown.
Compare	Identify the main factors relating to two or more items/situations or aspects of a subject that is extended to explain the similarities, differences, advantages and disadvantages. This is used to show depth of knowledge through selection of characteristics.
Compose	Create or make up or form.
Communicate	Convey ideas or information to others. Create/construct Skills to make or do something, for example a display or set of accounts.
Create/Construct	Skills to make or do something, for example a display or set of accounts.
Critically analyse	Separate information into components and identify characteristics with depth to the justification.
Critically evaluate	Make a judgement taking into account different factors and using available knowledge/experience/evidence where the judgement is supported in depth.
Define	State the nature, scope or meaning.
Describe	Give an account, including all the relevant characteristics, qualities and events.

Discuss	Consider different aspects of: • a theme or topic; • how they interrelate; and • the extent to which they are important.
Demonstrate	Show knowledge and understanding.
Design	Plan and present ideas to show the layout/function/workings/object/system/ Process.
Determine	To conclude or ascertain by research and calculation.
Develop	Grow or progress a plan, ideas, skills and understanding.
Differentiate	Recognise or determine what makes something different.
Discuss	Give an account that addresses a range of ideas and arguments
Evaluate	Work draws on varied information, themes or concepts to consider aspects, such as: • strengths or weaknesses • advantages or disadvantages • alternative actions • relevance or significance Students' inquiries should lead to a supported judgement showing relationship to its context. This will often be in a conclusion. Evidence will often be written but could be through presentation or activity.
Explain	To give an account of the purposes or reasons.
Explore	Skills and/or knowledge involving practical research or testing.
Identify	Indicate the main features or purpose of something by recognising it and/or being able to discern and understand facts or qualities.
Illustrate	Make clear by using examples or provide diagrams.
Indicate	Point out, show.
Interpret	State the meaning, purpose or qualities of something through the use of images, words or other expression.
Investigate	Conduct an inquiry or study into something to discover and examine facts and information.
Justify	Students give reasons or evidence to: • support an opinion; or • show something to be right or reasonable.
Outline	Set out the main points/characteristics.
Plan	Consider, set out and communicate what is to be done.

Produce	To bring into existence.
Reconstruct	To assemble again/reorganise/form an impression.
Report	Adhere to protocols, codes and conventions where, findings or judgements are set down in an objective way.
Review	Make a formal assessment of work produced. The assessment allows students to: • appraise existing information or prior events • reconsider information with the intention of making changes, if necessary.
Show how	Demonstrate the application of certain methods/theories/concepts.
Stage & Manage	Organisation and management skills, for example running an event or a business pitch.
State	Express.
Suggest	Give possible alternatives, produce an idea, put forward, e.g. an idea or plan, for consideration.
Undertake/Carry Out	Undertake/carry out. Use a range of skills to perform a task, research or activity.

This is a key summary of the types of evidence used for BTEC Higher Nationals:

Type of evidence	**Definition**
Case study	A specific example to which all students must select and apply knowledge.
Project	A large scale activity requiring self-direction of selection of outcome, planning, research, exploration, outcome and review.
Independent research	An analysis of substantive research organised by the student from secondary sources and, if applicable, primary sources.
Written task or report	Individual completion of a task in a work-related format, e.g. a report, marketing communication, set of instructions, giving information.
Simulated activity/ role play	A multi-faceted activity mimicking realistic work situations.
Team task	Students work together to show skills in defining and structuring activity as a team.
Presentation	Oral or through demonstration.
Production of plan/business plan	Students produce a plan as an outcome related to a given or limited task.
Reflective journal	Completion of a journal from work experience, detailing skills acquired for employability.
Poster/leaflet	Documents providing well-presented information for a given purpose.

Appendix 4: Assessment Methods and Techniques for Higher Nationals

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Academic graphic display	This technique asks students to create documents providing well-presented information for a given purpose. Could be hard or soft copy.	Creativity	Formative
		Written Communication	Summative
		Information and Communications Technology	
		Literacy	
Case Study	This technique present students with a specific example to which they must select and apply knowledge.	Reasoning	Formative
		Critical Thinking	Summative
		Analysis	
Discussion Forum	This technique allows students to express their understanding and perceptions about topics and questions presented in the class or digitally, for example online groups, blogs.	Oral/written Communication	Formative
		Appreciation of Diversity	
		Critical Thinking and Reasoning	
		Argumentation	
Examination	This technique covers all assessment that needs to be done within a centre-specified time constrained period on-site. Some units may be more suited to an exam-based assessment approach, to appropriately prepare students for further study such as progression on to Level 6 programmes or to meet professional recognition requirements.	Reasoning	Summative
		Analysis	
		Written Communication	
		Critical Thinking	
		Interpretation	
Independent Research	This technique is an analysis of research organised by the student from secondary sources and, if applicable, primary sources.	Information and Communications Technology	Formative
		Literacy	
		Analysis	
Oral/Viva	This technique asks students to display their knowledge of the subject via questioning.	Oral Communication	Summative
		Critical Thinking	
		Reasoning	

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Peer Review	This technique asks students to provide feedback on each other's performance. This feedback can be collated for development purposes.	Teamwork Negotiation Collaboration	Formative Summative
Presentation	This technique asks students to deliver a project orally or through demonstration.	Oral Communication Creativity Critical Thinking Reasoning	Formative Summative
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 Interpretation Written and oral Communication Decision-making Initiative Information and Communications Technology Literacy, etc.	Summative
Project	This technique is a large-scale activity requiring self-direction, planning, research, exploration, outcome and review.	Written Communication Information Literacy Creativity Initiative	Summative
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 Leadership Information Literacy Creativity Initiative	Formative

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Self-reflection	This technique asks students to reflect on their performance, for example, to write statements of their personal goals for the course at the beginning of the course, what they have learned at the end of the course and their assessment of their performance and contribution; completion of a reflective journal from work experience, detailing skills acquired for employability.	Self-reflection	Summative
		Written Communication	
		Initiative	
		Decision-making	
		Critical Thinking	
Simulated Activity	This technique is a multi-faceted activity based on realistic work situations.	Self-reflection	Formative
		Critical Thinking	Summative
		Initiative	
		Decision-making	
		Written Communication	
Team Assessment	This technique asks students to work together to show skills in defining and structuring an activity as a team. All team assessment should be distributed equally, each of the group members performing their role, and then the team collates the outcomes, and submits it as a single piece of work.	Collaboration	Formative
		Teamwork	Summative
		Leadership	
		Negotiation	
		Written and Oral Communication	
Time-constrained Assessment	This technique covers all assessment that needs to be done within a centre-specified time constrained period on-site.	Reasoning	Summative
		Analysis	
		Critical thinking	
		Interpretation	
		Written Communication	
Top Ten	This technique asks students to create a ‘top ten’ list of key concepts presented in the assigned reading list.	Teamwork	Formative
		Creativity	
		Analysis	
		Collaboration	

Assessment Technique	Description	Transferable Skills Development	Formative or Summative
Written Task or Report	This technique asks students to complete an assignment in a structured written format, for example, a project plan, a report, marketing communication, set of instructions, giving information.	Reasoning	Summative
		Analysis	
		Written Communication	
		Critical Thinking	
		Interpretation	

Ma040119V:\LT\PD\HIGHER NATIONALS\9781446959312_HNCD_L4_RAILENG\9781446959312_HNCD_L4_RAILENG.DOC.1–316/2

January 2019

For information about Pearson qualifications, including Pearson Edexcel and BTEC qualifications visit qualifications.pearson.com

Pearson Education Limited. Registered in England and Wales No. 872828
Registered Office: 80 Strand, London WC2R 0RL.

VAT Reg No GB 278 537121