Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

Pearson BTEC Level 3 Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

Specification

New Apprenticeship Standards – Specialist Qualification (England only)

First teaching September 2016

Issue 2
Edexcel, BTEC and LCCI qualifications

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This specification is Issue 2. Key changes are listed in the summary table on the next page. We will inform centres of any changes to this issue. The latest issue can be found on the Pearson website: qualifications.pearson.com

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Summary of specification Issue 2 changes for:

Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

Pearson BTEC Level 3 Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

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<td>An additional optional unit, Unit 51: Helicopter Gas Turbine Engines, Transmission, Rotors and Structures, has been added to the qualifications.</td>
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Earlier issue(s) show(s) previous changes.

If you need further information on these changes or what they mean, contact us via our website at: qualifications.pearson.com/en/support/contact-us.html.
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1 Introducing BTEC Specialist qualifications for the new Apprenticeship Standards in England

Overview

The current reforms to apprenticeships in England includes changes that move the design of apprenticeships into the hands of employers. The aim of this is to make apprenticeships more rigorous and responsive to employers’ needs. Employer groups, referred to as Trailblazers, now lead on the development of apprenticeships for occupations where they identify the need for apprentices.

Pearson has been working closely with Trailblazer employer groups in the development of different types of assessment programmes and qualifications, to support the delivery of these new apprenticeships.

As work-related qualifications, BTEC Specialist qualifications are well suited to the new apprenticeships. Through close collaboration with Trailblazer employer groups, these BTEC Specialist qualifications are designed to underpin the development of occupational competencies by giving learners the knowledge, understanding and skills relevant to the Apprenticeship Standards.

BTEC Specialist qualifications put learning in the context of the world of work, giving learners the opportunity to apply their research, skills and knowledge in relevant and realistic work contexts. This applied, practical approach also means that learners are further supported to progress in their career or further study.

Employers, or colleges and training centres, working in partnership with employers, can offer these qualifications as long as they have access to appropriate physical and human resources and that the necessary quality assurance systems are in place.

Sizes of BTEC Specialist qualifications

For all regulated qualifications, Pearson specify a total number of hours that it is estimated learners will require to complete and show achievement for the qualification – this is the Total Qualification Time (TQT). The TQT value indicates the size of a qualification.

Within the TQT, Pearson identifies the number of Guided Learning Hours (GLH) that we estimate a centre delivering the qualification might provide. Guided learning means activities, such as lessons, tutorials, online instruction, supervised study and giving feedback on performance, that directly involve tutors and assessors in teaching, supervising and invigilating learners. Guided learning includes the time required for learners to complete external assessment under examination or supervised conditions.

In addition to guided learning, other required learning directed by tutors or assessors will include private study, preparation for assessment and undertaking assessment when not under supervision, such as preparatory reading, revision and independent research.

As well as TQT and GLH, qualifications can also have a credit value – equal to one tenth of TQT, rounded to the nearest whole number.
TQT and credit values are assigned after consultation with users of the qualifications.

BTEC Specialist qualifications for the new Apprenticeship Standards are generally available in the following sizes:

- **Award** – a qualification with a TQT value of 120 or less (equivalent to a range of 1–12 credits)
- **Certificate** – a qualification with a TQT value in the range of 121–369 (equivalent to a range of 13–36 credits)
- **Diploma** – a qualification with a TQT value of 370 or more (equivalent to 37 credits and above).

Other size references, such as Extended Diploma, may be used in a suite of qualifications depending on the specific needs of different sectors and Trailblazer employer groups.
## 2 Qualification summary and key information

<table>
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<th>Qualification title</th>
<th>Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)</th>
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<tr>
<td>Qualification Number (QN)</td>
<td>601/9063/2</td>
</tr>
<tr>
<td>Regulation start date</td>
<td>20/06/2016</td>
</tr>
<tr>
<td>Operational start date</td>
<td>01/09/2016</td>
</tr>
</tbody>
</table>
| Approved age ranges | 16–18  
19+  
Please note that sector-specific requirements or regulations may prevent learners of a particular age from taking this qualification. Please refer to Section 7: Access and Recruitment. |
| Total Qualification Time (TQT) | 997 |
| Guided Learning Hours (GLH) | 720 |
| Assessment | Internal assessment and external assessment (2-hour written examination) |
| Grading information | The qualification and units are graded Pass/Merit/Distinction. |
| Entry requirements | No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification. In order to optimise success, candidates will typically have 4 GCSEs at Grade C or equivalent, including Mathematics, English and a Science. Employers who recruit candidates without English or Maths at Grade C or above must ensure that the candidate achieves this standard before completing the Apprenticeship.  
Centres must also follow the Pearson Access and Recruitment policy (see Section 7: Access and recruitment). |
| Funding | The Trailblazer Apprenticeship funding rules can be found on the Skills Funding Agency's website at: www.gov.uk/government/collections/sfa-funding-rules |
Qualification title: Pearson BTEC Level 3 Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

Qualification Number (QN): 601/9057/7
Regulation start date: 20/06/2016
Operational start date: 01/09/2016
Approved age ranges: 16–18
19+
Please note that sector-specific requirements or regulations may prevent learners of a particular age from taking this qualification. Please refer to Section 7: Access and Recruitment.

Total Qualification Time (TQT): 1501
Guided Learning Hours (GLH): 1080
Assessment: Internal assessment and external assessment (2 hour written examination)
Grading information: The qualification and units are graded Pass/Merit/Distinction.
Entry requirements: No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification. In order to optimise success, candidates will typically have 4 GCSEs at Grade C or equivalent, including Mathematics, English and a Science. Employers who recruit candidates without English or Maths at Grade C or above must ensure that the candidate achieves this standard before completing the Apprenticeship.
Centres must also follow the Pearson Access and Recruitment policy (see Section 7: Access and Recruitment).
Funding: The Trailblazer Apprenticeship funding rules can be found on the Skills Funding Agency's website at: www.gov.uk/government/collections/sfa-funding-rules

Learners must complete, as a minimum requirement, the 720 GLH Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge) to achieve the Development phase Technical Knowledge.
Some learners may want to extend the specialist nature of the subjects they studied on the 720 GLH Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge) and elect to complete the 1080 GLH Pearson BTEC Level 3 Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge) to achieve the Development phase Technical Knowledge.
Centres should use the Qualification Number (QN) when seeking funding for their learners. The qualification title, units and QN will appear on each learner’s certificate. You should tell your learners this when your centre recruits them and registers them with us. Further information about certification is given in our UK Information Manual, available on our website http://qualifications.pearson.com/en/support/support-topics/centre-administration/information-manual.html#tab-UK
3 Qualification purpose

Qualification objectives

The Pearson BTEC Level 3 Diploma and Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge) have been developed through close collaboration with the Aerospace and Aviation Apprenticeship employer group, professional bodies and other awarding organisations.

In both qualifications, learners have the opportunity to:

- develop the technical knowledge, understanding and skills required to meet the requirements of a number of Aerospace and Aviation Engineering Apprenticeship Standards. This includes areas such as mathematical techniques, principles of aircraft materials and airframe construction, aerodynamics and the theory of flight, and human factors and behaviours in aviation
- develop a range of positive attitudes and professional attributes that support successful performance in the aeronautical engineering work environment
- achieve a nationally-recognised Level 3 qualification.

Purpose of the Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

The Diploma in Aerospace and Aviation Engineering has been designed to meet the minimum requirements of the Apprenticeship Standards in Aerospace and Aviation Engineering. This qualification has been designed to meet the requirements of the Development Phase of the Apprenticeship Standards in Aerospace Engineering, including the manufacturing fitter role. The completion of this qualification is part of the gateway process towards End-point Assessment and ultimately achieving their Apprenticeship.

Purpose of the Pearson BTEC Level 3 Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

The Extended Diploma in Aerospace and Aviation Engineering has been designed to meet the requirements of the Development phase of the Apprenticeship Standards in Aerospace and Aviation Engineering, including the mechanical, electrical and system fitter roles. It has been designed for those employers who wish their Apprentices to complete additional optional units in other specialist areas to meet the needs of their business and to allow learners the ability to access higher education should they wish to progress further.

Apprenticeships

The Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge) is a mandatory requirement in the Apprenticeship Standard for: Aerospace Manufacturing Fitter (job roles: aircraft manufacture mechanical/aircraft power plant assembly). Learners must achieve this qualification before progressing to the End-point Assessment.
Role profile

Aerospace manufacturing fitters are predominantly involved in highly-skilled, complex and specialist detailed work, assembling aircraft systems according to specific work instructions, using relevant hand and machine tools, jigs and measuring equipment. They must comply with statutory regulations and organisational safety requirements. They must use and interpret engineering data and documentation such as engineering drawings and computer-generated printouts. They will be expected to work both individually and as part of a manufacturing team. They will be expected to test and adjust the systems they have installed, ensuring individual components and assemblies meet the required specification. The requirements are designed to offer stretch and progression. They will work with minimum supervision, taking responsibility for the quality and accuracy of the work they undertake. They will be proactive in finding solutions to problems and identifying areas for improving the business.

Core role requirements (knowledge and skills)

- Use of mathematical techniques, algebraic expressions, formulae and calculation to understand the theory of flight, aerodynamics and aviation manufacturing processes.
- Understand the structure, properties and characteristics of materials used in the construction of aero components, sub-assemblies and whole structures.
- Understand the fundamentals of electrical, electronic and fluid power theory.
- Reading and interpreting engineering data: reading and interpreting engineering drawings, specifications and computer-generated information.
- Business improvement techniques: designing manufacturing processes to be more efficient and cost effective.
- Assembly and disassembly of aero components, sub-assemblies and whole systems (new and service) as required.
- Measuring and marking out of materials to carry out precision machining and hand-fitting processes.
- Precision drilling and finishing of holes in aircraft assemblies.
- Complying with statutory, quality, organisational and health and safety regulations while carrying out manufacturing techniques.
- Safe selection and use of hand and mechanical tools and jigs while carrying out manufacturing procedures.
- Use of measuring and or test equipment, both mechanical and electronic, on aircraft assemblies and systems.
- Application of assembly techniques (mechanical fasteners, welding and bonding techniques).
- Sealing and jointing techniques: use of seals, gaskets, and jointing materials.
- Assembly of pipe work systems for engines and aircraft assemblies.
- Employer-tailored skills as required

Progression opportunities

Learners who achieve the Pearson BTEC Level 3 Diploma and/or Extended Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge) qualification will have achieved 15% of the overarching Apprenticeship requirements. On completing their Apprenticeship, learners can apply for Engineering Technician (EngTech) certification.

Learners who have achieved the qualification and not completed the full Apprenticeship could progress to engineering operative or semi-skilled fitter job roles in the engineering industry or to other qualifications such as the Pearson BTEC Level 3 Foundation Diploma in Engineering and the Pearson Edexcel Level 3 NVQ Diploma in Engineering Maintenance.

Industry support and recognition

The qualifications are supported by:

- the Aerospace and Aviation Apprenticeship Employer Group, which includes: BAE Systems, Airbus, MSM aerospace fabricators, Rolls-Royce, GKN Aerospace, Marshall Aerospace and Defence Group, Magellan Aerospace UK Ltd, GTA England
- professional engineering institutions, which include: the Institution of Engineering and Technology (IET), the Institution of Mechanical Engineers (IMechE) and the Royal Aeronautical Society (RAeS)
- Semta, the Skills Council for the Engineering sector
- the National Forum of Engineering Centres (NFEC).
4 Qualification structures

Pearson BTEC Level 3 Diploma in Aerospace and Aviation Engineering (Development Technical Knowledge)

Learners will need to meet the requirements outlined in the Qualification Units Table below before the qualification can be awarded.

| Minimum number of GLH that must be achieved | 720 |
| Number of mandatory GLH that must be achieved | 240 |
| Number of optional GLH that must be achieved | 480 |

QUALIFICATION UNITS TABLE

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<tr>
<th>Unit number</th>
<th>Mandatory units</th>
<th>Level</th>
<th>GLH</th>
<th>How assessed</th>
</tr>
</thead>
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<tr>
<td><strong>Mandatory units Group 1 – learners must complete all units in this group</strong></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>Health and Safety in the Engineering Workplace</td>
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<td>60</td>
<td>Internal</td>
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<td>2</td>
<td>Engineering Principles</td>
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<td>120</td>
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<th>Unit number</th>
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<th>Level</th>
<th>GLH</th>
<th>How assessed</th>
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<td>3</td>
<td>Aircraft Flight Principles and Practice</td>
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<tr>
<td>50</td>
<td>Helicopter Aerodynamics and Flight Principles</td>
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<table>
<thead>
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<th>Level</th>
<th>GLH</th>
<th>How assessed</th>
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<td><strong>Learners must complete a minimum of 480 GLH from this group</strong></td>
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<td>4</td>
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<td>5</td>
<td>Communications for Engineering Technicians</td>
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<td>6</td>
<td>Calculus to Solve Engineering Problems</td>
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<td>7</td>
<td>Further Engineering Mathematics</td>
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<td>9</td>
<td>Aircraft Workshop Methods and Practice</td>
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<td>10</td>
<td>Aircraft Gas Turbine Engines</td>
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<td>11</td>
<td>Aircraft Propulsion Systems</td>
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<td>12</td>
<td>Airframe Construction and Repair</td>
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<td>13</td>
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<tr>
<td>Unit number</td>
<td>Optional units</td>
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<td>GLH</td>
<td>How assessed</td>
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<td>14</td>
<td>Aircraft Electrical and Instrument Systems</td>
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<td>15</td>
<td>Aircraft First Line Maintenance Operations</td>
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<td>16</td>
<td>Properties and Applications of Engineering Materials</td>
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<td>17</td>
<td>Further Mechanical Principles and Applications</td>
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<td>18</td>
<td>Applications of Mechanical Systems in Engineering</td>
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<td>19</td>
<td>Organisational Efficiency and Improvement</td>
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<td>20</td>
<td>Electro-pneumatic and Hydraulic Systems and Devices</td>
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<td>60</td>
<td>Internal</td>
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<tr>
<td>21</td>
<td>Engineering Drawing for Technicians</td>
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<td>22</td>
<td>Computer-aided Drafting in Engineering</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<td>23</td>
<td>Advanced Mechanical Principles and Applications</td>
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<td>60</td>
<td>Internal</td>
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<td>24</td>
<td>Engineering Primary Forming Processes</td>
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<td>Engineering Secondary and Finishing Processes</td>
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<td>Internal</td>
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<td>26</td>
<td>Fabrication Processes and Technology</td>
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<td>Applications of Computer Numerical Control in Engineering</td>
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<td>Computer-aided Manufacturing</td>
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<td>Electronic Circuit Design and Manufacture</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<td>33</td>
<td>Principles and Applications of Electronic Devices and Circuits</td>
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<td>Engineering Maintenance Procedures and Techniques</td>
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<td>35</td>
<td>Monitoring and Fault Diagnosis of Engineering Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<td>36</td>
<td>Principles and Applications of Engineering Measurement Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>37</td>
<td>Electrical Technology</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<tr>
<td>Unit number</td>
<td>Optional units</td>
<td>Level</td>
<td>GLH</td>
<td>How assessed</td>
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<tr>
<td>38</td>
<td>Electrical Installation</td>
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<tr>
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<td>Electronic Measurement and Testing</td>
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</tr>
<tr>
<td>40</td>
<td>Features and Applications of Electrical Machines</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>41</td>
<td>Three-phase Motors and Drives</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<tr>
<td>42</td>
<td>Further Electrical Principles</td>
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<td>Manufacturing Planning</td>
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<td>Setting and Proving Secondary Processing Machines</td>
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<td>47</td>
<td>Industrial Process Controllers</td>
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<td>60</td>
<td>Internal</td>
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<tr>
<td>48</td>
<td>Principles and Operation of Three-phase Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>49</td>
<td>Industrial Robot Technology</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>51</td>
<td>Helicopter Gas Turbine Engines, Transmission, Rotors and Structures</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
</tbody>
</table>
Learners will need to meet the requirements outlined in the Qualification Units Table below before the qualification can be awarded.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
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<tbody>
<tr>
<td>Minimum number of GLH that must be achieved</td>
<td>1080</td>
</tr>
<tr>
<td>Number of mandatory GLH that must be achieved</td>
<td>240</td>
</tr>
<tr>
<td>Number of optional GLH that must be achieved</td>
<td>840</td>
</tr>
</tbody>
</table>

### QUALIFICATION UNITS TABLE

<table>
<thead>
<tr>
<th>Unit number</th>
<th>Mandatory units</th>
<th>Level</th>
<th>GLH</th>
<th>How assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Health and Safety in the Engineering Workplace</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>2</td>
<td>Engineering Principles</td>
<td>3</td>
<td>120</td>
<td>External</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit number</th>
<th>Mandatory optional units</th>
<th>Level</th>
<th>GLH</th>
<th>How assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Aircraft Flight Principles and Practice</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>50</td>
<td>Helicopter Aerodynamics and Flight Principles</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit number</th>
<th>Optional units</th>
<th>Level</th>
<th>GLH</th>
<th>How assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Engineering Project</td>
<td>3</td>
<td>120</td>
<td>Internal</td>
</tr>
<tr>
<td>5</td>
<td>Communications for Engineering Technicians</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>6</td>
<td>Calculus to Solve Engineering Problems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>7</td>
<td>Further Engineering Mathematics</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>8</td>
<td>Mechanical Measurement and Inspection Technology</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>9</td>
<td>Aircraft Workshop Methods and Practice</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>10</td>
<td>Aircraft Gas Turbine Engines</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>11</td>
<td>Aircraft Propulsion Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>12</td>
<td>Airframe Construction and Repair</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>13</td>
<td>Airframe Mechanical Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>14</td>
<td>Aircraft Electrical and Instrument Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>15</td>
<td>Aircraft First Line Maintenance Operations</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>Unit number</td>
<td>Optional units</td>
<td>Level</td>
<td>GLH</td>
<td>How assessed</td>
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</tr>
<tr>
<td>16</td>
<td>Properties and Applications of Engineering Materials</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>17</td>
<td>Further Mechanical Principles and Applications</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>18</td>
<td>Applications of Mechanical Systems in Engineering</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>19</td>
<td>Organisational Efficiency and Improvement</td>
<td>3</td>
<td>75</td>
<td>Internal</td>
</tr>
<tr>
<td>20</td>
<td>Electro-pneumatic and Hydraulic Systems and Devices</td>
<td>3</td>
<td>60</td>
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</tr>
<tr>
<td>21</td>
<td>Engineering Drawing for Technicians</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>22</td>
<td>Computer-aided Drafting in Engineering</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>23</td>
<td>Advanced Mechanical Principles and Applications</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>24</td>
<td>Engineering Primary Forming Processes</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>25</td>
<td>Engineering Secondary and Finishing Techniques</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>26</td>
<td>Fabrication Processes and Technology</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<tr>
<td>27</td>
<td>Welding Technology</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>28</td>
<td>Selecting and Using Programmable Controllers</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>29</td>
<td>Applications of Computer Numerical Control in Engineering</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>30</td>
<td>Welding Principles</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>31</td>
<td>Computer-aided Manufacturing</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>32</td>
<td>Electronic Circuit Design and Manufacture</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>33</td>
<td>Principles and Applications of Electronic Devices and Circuits</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
<tr>
<td>34</td>
<td>Engineering Maintenance Procedures and Techniques</td>
<td>3</td>
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<tr>
<td>35</td>
<td>Monitoring and Fault Diagnosis of Engineering Systems</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
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<tr>
<td>36</td>
<td>Principles and Applications of Engineering Measurement Systems</td>
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<td>Industrial Plant and Process Control</td>
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<td>48</td>
<td>Principles and Operation of Three-phase Systems</td>
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<td>49</td>
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<td>51</td>
<td>Helicopter Gas Turbine Engines, Transmission, Rotors and Structures</td>
<td>3</td>
<td>60</td>
<td>Internal</td>
</tr>
</tbody>
</table>
5 Programme delivery

Centres are free to offer these qualifications using any mode of delivery that meets learners’ and employers’ needs. It is recommended that centres make use of a wide range of training delivery methods, including direct instruction in classrooms, simulated demonstrations, research or applied projects, e-learning, directed self-study, field visits and role play. Whichever mode of delivery is used, centres must make sure that learners have access to the resources identified in the specification and to the subject specialists delivering the units.

Centres must adhere to the Pearson policies that apply to the different models of delivery. Our policy Collaborative Arrangements for the Delivery of Vocational Qualifications is available on our website.

Those planning the programme should aim to involve employers as far as possible in the delivery of the qualification. This could be by:

- spending time with employers to better understand their organisational requirements and the methods of training that are most suitable, taking into consideration available resources and working patterns
- collaborating with employers to ensure that learners have opportunities in the workplace to implement the knowledge and skills developed through the training programme
- having regular meetings with employers to discuss learner progress, providing feedback and agreeing how any issues will be resolved
- developing projects or assessments with input from employers
- developing up-to-date and relevant teaching materials that make use of scenarios relevant to the sector and relevant occupations
- using ‘expert witness’ reports from employers to support assessment
- making full use of the variety of experience of work and life that learners bring to the programme.

Where legislation is taught, centres must ensure that it is current and up to date.

- For further information on the delivery and assessment of the new Apprenticeships please refer to the Trailblazer Apprenticeships Funding Rules 2015 to 2016, at: www.gov.uk/government/collections/sfa-funding-rules
6 Centre resource requirements

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

General resource requirements

- Centres must have appropriate physical resources (e.g. IT, learning materials, teaching rooms) to support the delivery and assessment of the qualification.
- Staff involved in the delivery and assessment process must have relevant expertise and occupational experience.
- There must be systems in place that ensure continuing professional development (CPD) for staff delivering and assessing the qualification.
- Centres must have in place appropriate health and safety policies relating to the use of equipment by learners.
- Centres must have in place robust internal verification procedures to ensure the quality and authenticity of learners’ work, as well as the accuracy and consistency of assessment decisions between assessors operating at the centre. Further guidance will be provided to centres, following registration.
- Centres must deliver the qualifications in accordance with current equality legislation. For further details on Pearson’s commitment to the Equality Act 2010, please see Section 7: Access and recruitment. For full details of the Equality Act 2010, please go to www.legislation.gov.uk
7 Access and recruitment

Our policy on 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 barriers that restrict access and progression
- there should be equal opportunities for all wishing to access the qualifications.

Centres must ensure that their learner recruitment process is conducted with integrity. This includes ensuring that applicants have appropriate information and advice about the qualification to ensure that it will meet their needs.

Centres should review applicants’ prior qualifications and/or experience, considering whether this profile shows that they have the potential to achieve the qualification.

All learners undertaking an Apprenticeship Standard must be employed as an apprentice and have an Apprenticeship Agreement at the start of the first day of their apprenticeship programme.

Prior knowledge, skills and understanding

No prior knowledge, understanding, skills or qualifications are required before learners register for these qualifications. In order to optimise success, candidates will typically have 4 GCSEs at Grade C or equivalent, including Mathematics, English and a Science. Employers who recruit candidates without English or Maths at Grade C or above must ensure that the candidate achieves this standard prior to the completion of the Apprenticeship.

Access to qualifications for learners with disabilities or specific needs

Equality and fairness are central to our work. Pearson’s Equality Policy requires all learners to have equal opportunity to access our qualifications and assessments and that our qualifications are awarded in a way that is fair to every learner.

We are committed to making sure that:

- learners with a protected characteristic (as defined by the Equality Act 2010) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to learners who do not share that characteristic
- all learners achieve the recognition they deserve from undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

For learners with disabilities and specific needs, the assessment of their potential to achieve the qualification must identify, where appropriate, the support that will be made available to them during delivery and assessment of the qualification. Please see the information regarding reasonable adjustments and special consideration in Section 8: Assessment.
8 Assessment

The table below gives a summary of the assessment methods used in the two qualifications.

<table>
<thead>
<tr>
<th>Units</th>
<th>Assessment methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 2</td>
<td>External assessment – 2-hour written examination</td>
</tr>
<tr>
<td>Unit 1</td>
<td>Internal assessment (centre-devised assessment)</td>
</tr>
<tr>
<td>Unit 3</td>
<td>Internal assessment (centre-devised assessment)</td>
</tr>
<tr>
<td>Unit 50</td>
<td>Internal assessment (centre-devised assessment)</td>
</tr>
<tr>
<td>Units 4 to 51</td>
<td>Internal assessment (centre-devised assessment)</td>
</tr>
</tbody>
</table>

In administering internal and external assessments, centres need to be aware of the specific procedures and policies that apply to, for example, registration, entries and results. More information can be found in our *UK Information Manual*, available on our website.

**Language of assessment**

Assessments for internally-assessed units are in English only.

External assessments for units in this qualification will be available in English only.

Learners taking the qualification may be assessed in British or Irish Sign Language where it is permitted for the purpose of reasonable adjustment.

For further information on access arrangements, please refer to *Reasonable adjustments* later in this section.

**Internal assessment**

Most units in this qualification are internally assessed and subject to external standards verification. This means that centres set and mark the final summative assessment for each unit, using the examples and support that Pearson provides. Centres need to be, if they are not already, approved to offer the qualification before conducting assessments. *Section 9: Centre recognition and approval* gives information on approval for offering these qualifications.

**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 delivered. An assignment may take a variety of forms, including practical and written types. An assignment is a distinct activity, completed independently by learners, that is separate from teaching, practice, exploration and other activities that learners complete with direction from tutors and assessors.

An assignment is issued to learners as an assignment brief with a defined start date, completion date and clear requirements for the evidence that they need to provide. Assignments can be divided into tasks and may require several forms of evidence. A valid assignment will enable there to be a clear and formal assessment outcome based on the assessment criteria.
Designing effective assignments

Assignments must be fit for purpose as a tool to measure learning against the defined content and assessment criteria to ensure that final assessment decisions meet the required standard.

Centres should make sure that assignments enable learners to produce valid, sufficient, authentic and appropriate evidence that relates directly to the specified criteria within the context of the learning outcomes and unit content. Centres need to ensure that the generation of evidence is carefully monitored and controlled, and that it is produced to an appropriate timescale. This helps to make sure that learners are achieving to the best of their ability and at the same time that the evidence is genuinely their own.

An assignment that is fit for purpose and suitably controlled is one in which:

- the tasks that the learner is asked to complete provide evidence for a learning outcome that can be assessed using the assessment criteria
- the time allowed for the assignment is clearly defined and consistent with what is being assessed
- the centre has the required resources for all learners to complete the assignment fully and fairly
- the evidence the assignment will generate will be authentic and individual to the learner
- the evidence can be documented to show that the assessment and verification has been carried out correctly.

Recommended assignments are provided in the Assessment guidance section of a unit. In designing assignments, centres need to work within the structure of these assignments. Centres need to bear in mind the following points when developing their assignment briefs.

- Centres may choose to combine all or parts of different units into single assignments provided that all units and all their associated learning outcomes are fully addressed in the programme overall. If this approach is taken, centres need to make sure that learners are fully prepared so that they can provide all the required evidence for assessment and that centres are able to track achievement in the records.
- A learning outcome must always be assessed as a whole and must not be split into two or more assignments.
- 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.
- Centres do not have to follow the order of the learning outcomes of a unit in developing assignments but later learning outcomes often require learners to apply the content of earlier learning outcomes, and they may require learner to draw their learning together.
- Assignments must be structured to allow learners to demonstrate the full range of achievement at all grade levels. Learners 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 content is compulsory. The evidence for assessment need not cover every aspect of the teaching content as learners will normally be given particular examples, case
studies or contexts in their assignments. For example, if a learner is carrying out one practical performance 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 motivates learners to provide appropriate evidence of what they have learned through providing challenging and realistic tasks. An assignment brief should include:

- a vocational scenario, context or application for the tasks to be completed
- clear instructions to the learner 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

Centres may use a variety of forms of evidence, provided that they are suited to the type of learning outcome being assessed. For many units, the practical demonstration of skills is necessary and for others, learners will need to carry out their own research and analysis. The units give information on what would be suitable forms of evidence. Centres may choose to use different suitable forms for evidence to those proposed. Overall, learners should be assessed using varied forms of evidence.

Some of the main forms of evidence include:

- written task or reports
- projects
- time-constrained simulated activities with observation records and supporting evidence
- observation and recordings of performance in the workplace
- sketchbooks, working logbooks, reflective journals
- presentations with assessor questioning.

The form(s) of evidence selected must:

- allow the learner to provide all the evidence required for the learning outcome and the associated assessment criteria at all grade levels
- allow the learner to produce evidence that is their own independent work
- allow a verifier to independently reassess the learner 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 learners are enabled to produce independent work. For example, if learners are asked to use real examples, then best practice would be to encourage them to use their own experiences.

For information on the requirements for implementing assessment processes in centres, please refer to the BTEC UK Quality Assurance Handbook on our website.

**Making valid assessment decisions**

**Authenticity of learner work**

Once an assessment has begun, learners must not be given feedback on progress towards fulfilling the targeted criteria.

An assessor must assess only work that is authentic, i.e. learners’ own independent work. Learners must authenticate the evidence that they provide for assessment through signing a declaration stating that it is their own work.

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

Assessors must complete a declaration that:

- the evidence submitted for this assignment is the learner’s own
- the learner has clearly referenced any sources used in the work
- they understand that false declaration is a form of malpractice.

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 learner is not authentic. The assessor must then take appropriate action using the centre’s policies for malpractice. More information is given later in this section.

**Making assessment decisions using unit-based criteria**

Assessment decisions for the qualification are based on the specific criteria given in each unit and set at each grade level. The assessment criteria for a unit are hierarchical and holistic. For example, if an M criterion requires the learner to show ‘analysis’ and the related P criterion requires the learner to ‘explain’, then to satisfy the M criterion a learner will need to cover both ‘explain’ and ‘analyse’. The unit assessment grid shows the relationships between the criteria so that assessors can apply all the criteria to the learner’s evidence at the same time.

Assessors make judgements using the criteria and must show how they have reached their decisions in the assessment records. The evidence from a learner 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 Assessment guidance section of each unit, which gives examples and definitions related to terms used in the assessment criteria
● the centre’s Lead Internal Verifier and assessment team’s collective experience supported by the information provided by Pearson.

When a learner has completed the assessment for a unit then the assessment team will give an assessment outcome for the unit. This is given according to the highest level for which the learner is judged to have met all the criteria. Therefore:

● to achieve a Distinction, a learner must have satisfied all the Distinction criteria (and therefore the Pass and Merit criteria); these define outstanding performance across the unit as a whole

● to achieve a Merit, a learner must have satisfied all the Merit criteria (and therefore the Pass criteria) through high performance in each learning outcome.

● to achieve a Pass, a learner must have satisfied all the Pass criteria for the learning outcomes, showing coverage of the unit content and, therefore, attainment at the stated level of the qualification. The award of a Pass is a defined level of performance and cannot be given solely on the basis of a learner completing assignments. Learners who do not satisfy the Pass criteria should be reported as Unclassified.

**Dealing with late completion of assignments**

Learners must have a clear understanding of the centre’s policy on completing assignments by the stated deadlines. Learners may be given authorised extensions for legitimate reasons, such as illness at the time of submission, in line with centre policies.

For assessment to be fair, it is important that learners are all assessed in the same way and that some learners are not advantaged by having additional time or the opportunity to learn from others.

If a late completion is accepted, then the assignment should be assessed normally using the relevant assessment criteria.

**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 formally and reported to learners.

The information given to the learner:

● 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

● must be validated by an Internal Verifier before it is given to the learner.

**Resubmissions and retakes**

Learners who do not successfully pass an assignment are allowed to resubmit evidence for the assignment or to retake another assignment. As a matter of best practice, it is recommended that centres apply the BTEC Firsts and Nationals retake and resubmission rules; however as these rules are not mandatory for BTEC Specialist programmes at Entry Level to Level 3 they do not need to be applied.
Administrative arrangements for internal assessment

Records

Centres are required to retain records of assessment for each learner. Records should include assessments taken, decisions reached and any adjustments or appeals. Further information can be found in our UK Information Manual. We may ask to audit centre records so they must be retained as specified.

Reasonable adjustments to assessments

Centres are able to make adjustments to assessments to take account of the needs of individual learners, in line with the guidance given in the Pearson document *Supplementary guidance for reasonable adjustment and special consideration in vocational internally assessed units*. In most instances, adjustments can be achieved by following the guidance, for example allowing the use of assistive technology or adjusting the format of the evidence. We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. Any reasonable adjustment must reflect the normal learning or working practice of a learner in a centre or working within the occupational area.

Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document *Adjustments for candidates with disabilities and learning difficulties, Access Arrangements, Reasonable Adjustments and Special Consideration for General and Vocational qualifications*. Both documents are on the policy page of our website.

Special consideration

Centres must operate special consideration in line with the guidance given in the Pearson document *Supplementary guidance for reasonable adjustment and special consideration in vocational internally assessed units*. Special consideration may not be applicable in instances where:

- assessment requires the demonstration of practical competence
- criteria have to be met fully
- units/qualifications confer licence to practice.

Centres cannot apply their own special consideration; applications for special consideration must be made to Pearson and can be made on a case-by-case basis only. A separate application must be made for each learner. Certification claims must not be made until the outcome of the application has been received.

Further information on special consideration can be found in the JCQ document *Adjustments for candidates with disabilities and learning difficulties, Access Arrangements, Reasonable Adjustments and Special Consideration for General and Vocational qualifications*.

Both of the documents mentioned above are on our website.
**Appeals against assessment**

Centres must have a policy for dealing with appeals from learners. Appeals may relate to assessment decisions being incorrect or assessment not being conducted fairly. The first step in such a policy is a consideration of the evidence by a Lead Internal Verifier or other member of the programme team. The assessment plan should allow time for potential appeals after learners have been given assessment decisions.

Centres must document all learners’ appeals and their resolutions. Further information on the appeals process can be found in the document *Enquiries and Appeals about Pearson Vocational Qualifications policy*, which is available on our website.

**External assessment**

The table below gives information about the type and availability of external assessments for these qualifications. Centres should check this information carefully together with the relevant unit specification and the sample assessment materials so that they can timetable learning and assessment periods appropriately.

<table>
<thead>
<tr>
<th>Unit 2: Engineering Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of assessment</strong></td>
</tr>
<tr>
<td><strong>Length of assessment</strong></td>
</tr>
<tr>
<td><strong>Number of marks</strong></td>
</tr>
<tr>
<td><strong>Assessment availability</strong></td>
</tr>
<tr>
<td><strong>First assessment availability</strong></td>
</tr>
</tbody>
</table>

Pearson sets and marks the external assessments.

The content of the externally-assessed units will be sampled across different assessments over time. The way in which learners are assessed is shown through the assessment objectives and grading descriptors in each externally-assessed unit.

Centres need to make sure that learners are:

- fully prepared to sit the external assessments
- entered for the tests at appropriate times, with due regard for resit opportunities as necessary.
Sample assessment materials

The externally-assessed unit has a set of sample assessment materials (SAMs). The SAMs are there to provide an example of what the external assessment will look like in terms of the feel and level of demand of the assessment.

The SAMs show the range of possible question types that may appear in the actual assessments and give a good indication of how the assessments will be structured.

While SAMs can be used for practice with learners, as with any assessment the content covered and specific details of the questions asked will change in each assessment. A copy of each SAM can be downloaded from our website.

Administrative arrangements for external assessment

Access arrangements requests

Access arrangements are agreed with Pearson before an assessment. They allow learners with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

Access arrangements should always be processed at the time of registration. Learners will then know what type of arrangements are available in place for them.

Granting reasonable adjustments

For external assessment, a reasonable adjustment is one that Pearson agree to make for an individual learner. A reasonable adjustment is defined for the individual learner and informed by the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, including:

- the needs of the learner with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the learner with the disability and other learners.

Adjustment may be judged unreasonable and not approved if it involves unreasonable costs, timeframes or affects the integrity of the assessment.

Special consideration requests

Special consideration is an adjustment made to a learner’s mark or grade after an external assessment to reflect temporary injury, illness or other indisposition at the time of the assessment. An adjustment is made only if the impact on the learner is such that it is reasonably likely to have had a material effect on that learner being able to demonstrate attainment in the assessment.

Centres are required to notify us promptly of any learners that they believe have been adversely affected and request that we give special consideration. Further information can be found in the special requirements section on our website.
Conducting external assessments

Centres must make arrangements for the secure delivery of external assessments. All centres offering external assessments must comply with the Joint Council for Qualifications (JCQ) document *Instructions for the Conduct of Examinations (ICE)*. The current version of this document is available on our website.

Dealing with malpractice in assessment

Malpractice means acts that undermine the integrity and validity of assessment, the certification of qualifications and/or may damage the authority of those responsible for delivering the assessment and certification.

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

Malpractice may arise or be suspected in relation to any unit or type of assessment within the qualification. For further details on malpractice and advice on preventing malpractice by learners, please see Pearson's *Centre Guidance: Dealing with Malpractice*, available on our website.

The procedures we ask you to adopt vary between units that are internally assessed and those that are externally assessed.

Internal assessment

Centres are required to take steps to prevent malpractice and to investigate instances of suspected malpractice. Learners must be given information that explains what malpractice is for internal assessment and how suspected incidents will be dealt with by the centre. The *Centre Guidance: Dealing with Malpractice* document gives full information on the actions we expect you to take.

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

In the interests of learners and centre staff, centres need to respond effectively and openly to all requests relating to an investigation into an incident of suspected malpractice.

External assessment

External assessment means all aspects of units that are designated as external in this specification, including preparation for tasks and performance. For these assessments, centres must follow the JCQ procedures set out in the latest version of the document *JCQ Suspected Malpractice in Examinations and Assessments Policies and Procedures* (available on the JCQ website, www.jcq.org.uk).

In the interests of learners and centre staff, centres need to respond effectively and openly to all requests relating to an investigation into an incident of suspected malpractice.
Learner malpractice

The head of centre is required to report incidents of suspected learner malpractice that occur during Pearson examinations. We ask centres to complete JCQ Form M1 (www.jcq.org.uk/malpractice) and email it with any accompanying documents (signed statements from the learner, 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 learners lies with Pearson.

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

Teacher/centre malpractice

The head of centre is required to inform Pearson’s Investigations Team of any incident of suspected malpractice by centre staff, before any investigation is undertaken. The head of centre is requested to inform the Investigations Team by submitting a JCQ Form M2(a) (downloadable from www.jcq.org.uk/malpractice) with supporting documentation to pqsmalpractice@pearson.com. Where Pearson receives allegations of malpractice from other sources (for example Pearson staff, 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 learners) 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 learners and centre staff suspected of malpractice of their responsibilities and rights, please see 6.15 of JCQ Suspected Malpractice in Examinations and Assessments Policies and Procedures.

Pearson reserves the right in cases of suspected malpractice to withhold the issuing of results/certificates while an investigation is in progress. Depending on the outcome of the investigation, results and/or certificates may not be released or they may be 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

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

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

- mark reduction for affected external assessments
- disqualification from the qualification
- debarment from registration for Pearson qualifications for a period of time.
If we are concerned about your centre’s quality procedures we may impose sanctions such as:

- working with centres to create an improvement action plan
- requiring staff members to receive further training
- placing temporary blocks on the centre's certificates
- placing temporary blocks on registration of learners
- debarring staff members or the centre from delivering Pearson qualifications
- suspending or withdrawing centre approval status.

The centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from the head of centre (on behalf of learners 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 on our website. In the initial stage of any aspect of malpractice, please notify the Investigations Team (via pqsmalpractice@pearson.com) who will inform you of the next steps.
9 Centre recognition and approval

Centres offering mandatory qualifications for the New Apprenticeship Standards must be listed on the Skills Funding Agency’s Register of Training Organisations and have a contract to deliver the New Apprenticeships Standards.

Centres that have not previously offered Pearson Specialist qualifications need to apply for and be granted centre recognition and approval to offer individual qualifications.

Existing Pearson centres seeking approval to offer BTEC Specialist qualifications for the New Apprenticeship Standards, will be required to submit supplementary evidence for approval, aligned with the associated new standards and assessment requirements.

Guidance on seeking approval to deliver BTEC qualifications is available on our website.

Approvals agreement

All centres are required to enter into an approval agreement with Pearson, in which the head of centre or principal agrees to meet all the requirements of the qualification specification and to comply with the policies, procedures, codes of practice and regulations of Pearson and relevant regulatory bodies. If centres do not comply with the agreement, this could result in the suspension of certification or withdrawal of centre or qualification approval.
10 Quality assurance

Quality assurance is at the heart of vocational qualifications and Apprenticeships. Centres are required to declare their commitment to ensuring quality and to giving learners appropriate opportunities that lead to valid and accurate assessment outcomes.

Pearson uses external quality assurance processes to verify that assessment, internal quality assurance and evidence of achievement meet nationally defined standards. Our processes enable us to recognise good practice, effectively manage risk and support centres to safeguard certification and quality standards.

Our Standards Verifiers provide advice and guidance to enable centres to hold accurate assessment records and assess learners appropriately, consistently and fairly. The exact frequency and duration of Standards Verifier visits will reflect the level of risk associated with a programme, taking account of the:

- number of assessment sites
- number and throughput of learners
- number and turnover of assessors
- number and turnover of internal verifiers
- amount of previous experience of delivery.

If a centre is offering a BTEC Specialist qualification alongside other qualifications related to the same Apprenticeship Standard, wherever possible, we will allocate the same Standards Verifier for both qualifications.

Following registration, centres will be given further quality assurance and sampling guidance.
11 Understanding the qualification grade

This section explains the rules that we apply in providing an overall qualification grade for each learner. It shows how all the qualifications in this sector are graded.

The final grade awarded for a qualification represents a holistic performance across all of the qualification. As the qualification grade is an aggregate of the total performance, there is some element of compensation in that a higher performance in some units will be balanced by a lower outcome in others.

In the event that a learner achieves more than the required number of optional units, the mandatory units along with the optional units with the highest grades will be used to calculate the overall result, subject to the eligibility requirements for that particular qualification title.

Awarding and reporting for the qualification

The awarding and certification of these qualifications will comply with the requirements of the Office of Qualifications and Examinations Regulation (Ofqual).

Eligibility for an award

To achieve any qualification grade learners must:

- achieve a Pass grade, or higher in all units within a valid combination, and
- achieve the minimum number of points at a grade threshold.

It is the responsibility of a centre to ensure that a correct unit combination is adhered to.

Calculation of the qualification grade

The qualification grade is an aggregation of a learner’s unit level performance. The Diploma and Extended Diploma are awarded at the grade ranges shown in the table below.

<table>
<thead>
<tr>
<th>Qualification</th>
<th>Available grade range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diploma</td>
<td>P to D</td>
</tr>
<tr>
<td>Extended Diploma</td>
<td>P to D</td>
</tr>
</tbody>
</table>

The Calculation of Qualification Grade table, shown further on in this section, shows the minimum thresholds for calculating these grades.

Learners who do not meet the minimum requirements for a qualification grade to be awarded will be recorded as Unclassified (U) and will not be certificated. They may receive a Notification of Performance for individual units. The Information Manual gives full information.
Points available for internal units
The table below shows the number of points available for internal units. For each internal unit, points are allocated depending on the grade awarded.

<table>
<thead>
<tr>
<th>Unit size</th>
<th>Unit size</th>
<th>Unit size</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 GLH</td>
<td>75 GLH</td>
<td>120 GLH</td>
</tr>
<tr>
<td>U</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pass</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Merit</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Distinction</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

Points available for the external unit
The external unit will be awarded points based on performance in the assessment. The points scores available for the external unit are as follows.

<table>
<thead>
<tr>
<th>Unit size</th>
<th>Unit size</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 GLH</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>0</td>
</tr>
<tr>
<td>Pass</td>
<td>12</td>
</tr>
<tr>
<td>Merit</td>
<td>20</td>
</tr>
<tr>
<td>Distinction</td>
<td>32</td>
</tr>
</tbody>
</table>

Pearson will automatically calculate the points for each external unit once the external assessment has been marked and grade boundaries have been set. For more details about how we set grade boundaries in the external assessment please go to our website.

Claiming the qualification grade
Subject to eligibility, Pearson will automatically calculate the qualification grade for your learners when the internal unit grades are submitted and the qualification claim is made. Learners will be awarded qualification grades for achieving the sufficient number of points within the ranges shown in the applicable Calculation of Qualification Grade table.
## Calculation of Qualification Grade Table

Applicable for registration from 1 September 2016.

<table>
<thead>
<tr>
<th>Diploma</th>
<th>Extended Diploma</th>
</tr>
</thead>
<tbody>
<tr>
<td>720 GLH</td>
<td>1080 GLH</td>
</tr>
<tr>
<td>Grade</td>
<td>Points threshold</td>
</tr>
<tr>
<td>U</td>
<td>0</td>
</tr>
<tr>
<td>P</td>
<td>72</td>
</tr>
<tr>
<td>M</td>
<td>104</td>
</tr>
<tr>
<td>D</td>
<td>144</td>
</tr>
</tbody>
</table>
### Examples of grade calculations

#### Example 1: Achievement of a Diploma with a P grade

<table>
<thead>
<tr>
<th>GLH</th>
<th>Type (Int/Ext)</th>
<th>Grade</th>
<th>Unit points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit B</td>
<td>120</td>
<td>Ext</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit C</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit D</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit E</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit F</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit G</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit H</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit I</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit J</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit K</td>
<td>75</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Totals</td>
<td>735</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The learner has sufficient points for a P grade.

The learner has exceeded the 72 point pass threshold and has passed all units.
### Example 2: Achievement of a Diploma with a D grade

<table>
<thead>
<tr>
<th>GLH</th>
<th>Type (Int/Ext)</th>
<th>Grade</th>
<th>Unit points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit B</td>
<td>120</td>
<td>Ext</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit C</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit D</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit E</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit F</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit G</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
</tr>
<tr>
<td>Unit H</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
</tr>
<tr>
<td>Unit I</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
</tr>
<tr>
<td>Unit J</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
</tr>
<tr>
<td>Unit K</td>
<td>75</td>
<td>Int</td>
<td>Distinction</td>
</tr>
<tr>
<td>Totals</td>
<td>735</td>
<td>D</td>
<td>146</td>
</tr>
</tbody>
</table>

The learner has exceeded the 144 threshold for Distinction and has passed all units.
Example 3: An Unclassified result for a Diploma

<table>
<thead>
<tr>
<th>GLH</th>
<th>Type (Int/Ext)</th>
<th>Grade</th>
<th>Unit points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit B</td>
<td>120</td>
<td>Ext</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit C</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit D</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit E</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit F</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit G</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
</tr>
<tr>
<td>Unit H</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit I</td>
<td>60</td>
<td>Int</td>
<td>U</td>
</tr>
<tr>
<td>Unit J</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Unit K</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
</tr>
<tr>
<td>Totals</td>
<td>720</td>
<td></td>
<td>U</td>
</tr>
</tbody>
</table>

The learner has sufficient points for a Pass (72) but has not passed all units. Hence the grade is U.
Example 4: Extended Diploma Pass

<table>
<thead>
<tr>
<th></th>
<th>GLH</th>
<th>Type (Int/Ext)</th>
<th>Grade</th>
<th>Unit points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit B</td>
<td>120</td>
<td>Ext</td>
<td>Pass</td>
<td>12</td>
</tr>
<tr>
<td>Unit C</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit D</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit E</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit F</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>Unit G</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>Unit H</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit I</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit J</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>Unit K</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>Unit L</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit M</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit N</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit O</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit P</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit Q</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Totals</td>
<td>1080</td>
<td></td>
<td></td>
<td>P 134</td>
</tr>
</tbody>
</table>

The learner has exceeded the 108 point pass threshold, and has passed all units.
### Example 5: Extended Diploma Distinction

<table>
<thead>
<tr>
<th>Unit</th>
<th>GLH</th>
<th>Type (Int/Ext)</th>
<th>Grade</th>
<th>Unit points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit B</td>
<td>120</td>
<td>Ext</td>
<td>Pass</td>
<td>12</td>
</tr>
<tr>
<td>Unit C</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit D</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit E</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit F</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit G</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit H</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit I</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit J</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit K</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit L</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit M</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit N</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit O</td>
<td>60</td>
<td>Int</td>
<td>Distinction</td>
<td>16</td>
</tr>
<tr>
<td>Unit P</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Unit Q</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>1080</strong></td>
<td><strong>D</strong></td>
<td><strong>222</strong></td>
<td></td>
</tr>
</tbody>
</table>

The learner has exceeded the 216 point distinction threshold and passed all units.
### Example 6: An Unclassified result for an Extended Diploma

<table>
<thead>
<tr>
<th>Unit</th>
<th>GLH</th>
<th>Type (Int/Ext)</th>
<th>Grade</th>
<th>Unit points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>120</td>
<td>Ext</td>
<td>U</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>F</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>H</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>I</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>J</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>K</td>
<td>60</td>
<td>Int</td>
<td>Merit</td>
<td>10</td>
</tr>
<tr>
<td>L</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>M</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>N</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>O</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>P</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td>Q</td>
<td>60</td>
<td>Int</td>
<td>Pass</td>
<td>6</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>1080</strong></td>
<td><strong>U</strong></td>
<td><strong>116</strong></td>
<td></td>
</tr>
</tbody>
</table>

The learner has exceeded the 108 point pass threshold but has not passed all units.
# 12 Units

Each unit in the specification is set out in a similar way. There are two types of unit format:

- internal units
- external units.

This section explains how the units are structured. It is important that all tutors, assessors, internal verifiers and other staff responsible for the programme review this section.

## Internal units

<table>
<thead>
<tr>
<th>Section</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit number</strong></td>
<td>The number is in a sequence in the specification. Where a specification has more than one qualification, numbers may not be sequential for an individual qualification.</td>
</tr>
<tr>
<td><strong>Unit title</strong></td>
<td>This is the formal title that will always be used and which will appear on certificates.</td>
</tr>
<tr>
<td><strong>Level</strong></td>
<td>All units and qualifications have a level assigned to them. The level assigned is informed by the level descriptors defined by Ofqual, the qualifications regulator.</td>
</tr>
<tr>
<td><strong>Unit type</strong></td>
<td>This says if the unit is mandatory or optional for the qualification. See structure information in Section 4 for full details.</td>
</tr>
<tr>
<td><strong>Assessment type</strong></td>
<td>This says how the unit is assessed – i.e. whether it is internal or external. See information in Section 4 Qualification structure for details.</td>
</tr>
<tr>
<td><strong>Guided learning hours (GLH)</strong></td>
<td>This indicates the number of hours of activities that directly or immediately involve tutors and assessors in teaching, supervising, and invigilating learners. Units may vary in size.</td>
</tr>
<tr>
<td><strong>Unit introduction</strong></td>
<td>This is designed with learners in mind. It indicates why the unit is important, what will be learned and how the learning might be applied in the workplace.</td>
</tr>
<tr>
<td><strong>Learning outcomes</strong></td>
<td>These help to define the scope, style and depth of learning of the unit.</td>
</tr>
<tr>
<td><strong>Unit content</strong></td>
<td>This section sets out the required teaching content of the unit. Content is compulsory except when shown as ‘e.g.’. Learners should be asked to complete summative assessment only after the teaching of content for the unit or learning outcome(s) has been covered.</td>
</tr>
<tr>
<td><strong>Assessment and grading criteria</strong></td>
<td>Assessment criteria specify the standard required by the learner to achieve each learning outcome. Each learning outcome has Pass criteria. In addition to Pass criteria, each learning outcome has Merit or both Merit and Distinction criteria.</td>
</tr>
<tr>
<td>Section</td>
<td>Explanation</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Essential guidance for tutors</td>
<td>This section gives information to support the implementation of assessment. It is important that this information is used carefully, alongside the assessment criteria. This information gives guidance for each learning outcome or assignment of the expectations for Pass, Merit and Distinction standard. This section contains examples and essential clarification.</td>
</tr>
<tr>
<td>Programme of suggested assignments</td>
<td>This section shows a programme of suggested assignments that covers the Pass, Merit and Distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.</td>
</tr>
<tr>
<td>Essential resources</td>
<td>This section lists any specific resources that are needed to be able to teach and assess the unit.</td>
</tr>
<tr>
<td>Indicative reading for learners</td>
<td>Lists resource materials that can be used to support the teaching of the unit, for example books, journals, websites.</td>
</tr>
</tbody>
</table>
### External units

<table>
<thead>
<tr>
<th>Section</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit number</td>
<td>The number is in a sequence in the specification. Where a specification has more than one qualification, numbers may not be sequential for an individual qualification.</td>
</tr>
<tr>
<td>Unit title</td>
<td>This is the formal title that will always be used and which will appear on certificates.</td>
</tr>
<tr>
<td>Level</td>
<td>All units and qualifications have a level assigned to them. The level assigned is informed by the level descriptors defined by Ofqual, the qualifications regulator.</td>
</tr>
<tr>
<td>Unit type</td>
<td>This says if the unit is mandatory or optional for the qualification. See information in Section 4 Qualification structure for full details.</td>
</tr>
<tr>
<td>Guided learning hours (GLH)</td>
<td>This indicates the number of hours of activities that directly or immediately involve tutors and assessors in teaching, supervising, and invigilating learners Units may vary in size.</td>
</tr>
<tr>
<td>Unit introduction</td>
<td>This is designed with learners in mind. It indicates why the unit is important, what will be learned and how the learning might be applied in the workplace.</td>
</tr>
<tr>
<td>Summary of assessment</td>
<td>This sets out the type of external assessment used and the way in which it is used to assess achievement</td>
</tr>
<tr>
<td>Assessment objectives</td>
<td>These help to define the scope, style and depth of learning of the unit.</td>
</tr>
<tr>
<td>Essential content</td>
<td>For external units, all the content is obligatory, the depth of content is indicated in the assessment outcomes and sample assessment materials (SAMs). The content will be sampled through the external assessment over time, using the variety of questions or tasks shown.</td>
</tr>
<tr>
<td>Grade descriptors</td>
<td>We use grading descriptors when making judgements on grade boundaries. You can use them to understand what we expect to see from learners at particular grades.</td>
</tr>
<tr>
<td>Key terms typically used in assessment</td>
<td>These definitions will help you to analyse requirements and prepare learners for assessment.</td>
</tr>
</tbody>
</table>
Unit 1: Health and Safety in the Engineering Workplace

Level: 3
Unit type: Mandatory
Assessment type: Internal
Guided learning: 60

Unit introduction

The welfare of people working or operating in any manufacturing or engineering environment is of prime importance. All workers should be able to carry out their work in a safe manner that has no negative effect on their health and wellbeing. In fact, many organisations not only reduce risks and make improvements to the working environment, but try to make their own working environment superior to others, making it a competitive aspect when recruiting staff.

Health and safety in the workplace is about measures designed to protect the health and safety of employees, visitors and the general public who may be affected by workplace activities. Safety measures are concerned with controlling and reducing risks to anyone who might be affected by these activities.

Health and safety is controlled largely by legislation and regulations, with the law being continually revised and updated. It is important that organisations are aware of these changes and keep up to date with developments.

This unit will give learners an understanding of hazards and risks associated with health, safety and welfare in an engineering workplace, the associated legislation and regulations, and of their roles in complying with the related legal obligations. Learners will be required to undertake full risk assessments and to appreciate the significant risks encountered in the workplace and the measures taken to deal with them. They will study the principles of reporting and recording accidents and incidents, again within a legal context.

This unit could form a key component in many learning programmes since the content is highly applicable to many manufacturing, engineering and industrial situations.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand health and safety legislation and regulations
2. Know about hazards and risks in the workplace
3. Understand the methods used when reporting and recording accidents and incidents.
Unit content

1 Understand health and safety legislation and regulations

Key features of legislation and regulations: the general contents of legislation and regulations or other relevant international equivalents and how they are satisfied by safe systems of work/procedures, including:

- Health and Safety at Work etc. Act 1974 – duties of employers, employees, Health and Safety Executive (HSE) and others, general prohibitions

- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013 (as amended) – duties of employers, self-employed and people in control of work premises (the Responsible Person) to report certain serious workplace accidents, occupational diseases and specified dangerous occurrences

- Personal Protective Equipment (PPE) at Work Regulations 1992 (as amended) – appropriate if risk cannot be controlled in any other way, types, assessing suitable PPE given the hazard, supply, instructions/training, correct use, maintenance and storage

- Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended) – identifying harmful substances, assessing risks of exposure, types of exposure, safety data sheets, using/checking/maintaining control measures/equipment, training/instruction/information

- Manual Handling Operations Regulations (MHOR) 1992 (as amended) – avoid the need for manual handling, types of hazard, assess risk of injury when manual handling is required, control and reduce the risk of injury, training in use of techniques/mechanical aids

- Environmental legislation and EU directives: Environmental Protection Act 1990; Pollution Prevention and Control Act 1999; Clean Air Act 1993; Radioactive Substances Act 1993; Controlled Waste Regulations 2012; Controls on Dangerous Substances and Preparations Regulations 2006

Roles and responsibilities of those involved: employers; employees; HSE, e.g. span of authority, right of inspection, guidance notes and booklets; others, e.g. management, subcontractors, public, suppliers, customers, visitors

Application of environmental management systems: ISO 14000 (family of standards, a management tool); environmental management (what an organisation does to minimise the harmful effects on the environment caused by its activities); ISO 14004 (guidelines on the elements of an environmental management system and its implementation, and examines principle issues involved); ISO 14001 (specifies the requirements for such an environmental management system)
2 Know about hazards and risks in the workplace

In the workplace: methods to identify hazards, e.g. statements, analysis of significant risks, prediction of results or outcomes of those risks, use of accident data, careful consideration of work methods

Working environment: consideration of the workplace and its potential for harm, e.g. confined spaces, working over water or at heights, electrical hazards, chemicals, noise

Hazards that become risks: identification of trivial or significant risk; potential to cause harm; choosing appropriate control measures; electrical safety, e.g. identifying and controlling hazards, cause of injury, effects of electricity on the body, circuit overloading; mechanical safety, e.g. identifying and controlling hazards, cause of injury, rotating equipment, sharp edges; safety devices, e.g. residual current device (RCD), fuses, guards, fail safe, sensors

Risk assessments: items/area to be assessed, e.g. machine operation, work area; five steps (principal hazards, who is likely to be injured/harmed, evaluation of the risks and decisions on adequacy of precautions, recording findings, review assessment)

Use of control measures: e.g. removing need (design out), use of recognised procedures, substances control, guarding, lifting assessments and manual handling assessments, regular inspection, use of PPE, training of personnel, other personal procedures for health, safety and welfare

Application of aids to lift or move loads: e.g. pinch bars, rollers, skates, pallet trucks, scissor lifts, forklift trucks, wall and overhead cranes; ancillary equipment, e.g. block and tackle, pull lifts, slings (chain, rope, polyester), shortening clutches, lifting/plate clamps, eye bolts (dynamo, collar), shackles (dee, bow)

Regulations: e.g. Provision and Use of Workplace Equipment Regulations (PUWER) 1998, Lifting Operations and Lifting Equipment Regulations (LOLER) 1998

Procedures: safe working load (SWL) capacity of equipment; 1200 maximum spread on slings when lifting; ensuring clearway and not moving loads over others heads; not transporting people on loads; correct hand signals from floor staff to crane drivers; protection of chains and slings from sharp corners; setting hooks and sling/chain lengths correctly

Storage of gases, oil, acids, adhesives and engineering materials: COSHH regulations; structure of storage buildings, stillages and shelving; control of ventilation, extraction and temperature; good housekeeping and stock management; storage of flammable liquids/compressed gases, oil, acids and adhesives

3 Understand the methods used when reporting and recording accidents and incidents

Principles: why employers keep records of serious accidents, incidents and emergencies; responsibilities of competent persons; cost of accidents, e.g. direct, indirect, human consequences; trends, e.g. major causes, fatal and serious injury, methods of classification, statistics.

Recording and reporting procedures: regulations on accident recording and reporting, e.g. RIDDOR 1995, accident book, company procedures; procedures to deal with near misses or dangerous occurrences
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong> explain the key features of relevant regulations on health and safety as applied to a working environment in two selected or given engineering organisations</td>
<td><strong>M1</strong> explain the consequences of management not abiding by legislation and regulations when carrying out their roles and responsibilities in a given health and safety situation</td>
<td><strong>D1</strong> assess the extent to which legislation and regulations are satisfied in a given health and safety situation</td>
</tr>
<tr>
<td><strong>P2</strong> describe the roles and responsibilities under current health and safety legislation and regulations of those involved in two selected or given engineering organisations</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> explain the key features of the relevant legislation and EU directives, with regard to environmental management</td>
<td><strong>M2</strong> explain the consequences of management not abiding by legislation and regulations when carrying out their roles and responsibilities, with regard to environmental management</td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> explain the requirements for the safe disposal of waste</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P5</strong> describe the methods used to identify hazards in a working environment</td>
<td><strong>M3</strong> explain how hazards that become risks can be controlled</td>
<td><strong>D2</strong> justify the methods used to deal with hazards in accordance with workplace policies and legal requirements</td>
</tr>
<tr>
<td><strong>P6</strong> carry out a risk assessment on a typical item/area of the working environment</td>
<td><strong>M4</strong> explain the importance of carrying out all parts of a risk assessment in a suitable manner</td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> suggest suitable control measures after a risk assessment has been carried out and state the reasons why they are suitable</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> suggest a suitable process or equipment to assist in moving different loads correctly and safely</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> describe the precautions needed for the safe storage of gases, oil, acids, adhesives and engineering materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P10</strong> explain the principles that underpin reporting and recording accidents and incidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P11</strong> describe the procedures used to record and report accidents, dangerous occurrences or near misses.</td>
<td><strong>M5</strong> explain how control measures are used to prevent accidents.</td>
<td><strong>D3</strong> assess the potential costs and implications for the organisation and the individual as a result of an accident in the workplace.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Evidence of criteria can be collected from case studies, assignments and projects, which should enable learners to explore the application of legislation and regulations, and hazards and risks in the workplace.

The pass grade specifies the minimum acceptable level required by learners. Assessment will need to cover all the learning outcomes but not necessarily all the topics included in the unit content. Achievement of a merit or a distinction grade will require answers that demonstrate additional depth and/or breadth of treatment.

To achieve a pass, learners must demonstrate an understanding of health, safety and welfare issues as applied to engineering processes and companies. They will need to explain the key features of legislation and regulations and describe a range of roles and responsibilities. They will understand the connection between hazard identification, risk assessment and accident prevention. Learners will carry out a risk assessment, suggest suitable controls and show they understand the principles and procedures for reporting and recording accidents and other occurrences relative to health and safety.

This unit could be assessed through three assignments. The first assignment could have a series of written tasks. The first task could ask learners to research and then explain the key features of relevant regulations as applied to two separate working environments (P1). It would be expected that at least four regulations should be considered across the two selected or given engineering organisations.

Another task could require them to describe the roles and responsibilities of those involved in the environments selected above (P2). The organisations selected could include learners’ places of work, or a training workshop or machine shop environment. A combination of one electrical and one mechanical type would be most appropriate. The assignment should cover legislation and regulations. It is not expected that all the legislation and regulations listed in the content would be covered, just those applicable to the given context.

The roles and responsibilities of those involved could include employers, employees, the HSE and any one from the list of others in the unit content. A further task could then be used, asking learners to explain the consequences of management not abiding by legislation and regulations when carrying out their roles and responsibilities in one of these situations (M1). For the same situation, learners could carry out research to assess how the legislation and regulations are satisfied (D1). They might consider reviewing workplace incident/accident records/reports.

P3 and M2 could be achieved using a similar approach and applying this to environmental management. All responses could be in a written format, although for the pass criteria a presentation to the class or annotated poster could be used. In these cases it must be remembered that the presentation skills or poster design skills are not being assessed.

The second assignment could cover P4 to P9, along with the higher criteria M3, M4 and D2. The whole assignment could be based on a practical activity to produce a risk assessment on a typical item or area of a working environment. Again, this working environment could be learners’ workplace or one from the centre’s own workshops. Whichever item or area is chosen, it should have a range of hazards that can be identified, for example a machining operation or electrical assembly/wiring type activity could be used.
Written tasks would have to be set to give learners opportunities to achieve the explanations required for P4 to P9, M3 and M4, and the justification required for D2. P7 could be achieved through an oral question and answer session after carrying out the risk assessment. A standard template can be used to capture the outcomes of the risk assessment as this is what would be found in normal company use. A witness statement/observation record could be used to show learner performance against the requirement of P6.

The final assignment could cover the remaining criteria P10, P11, M5 and D3, with a written task given for each. Learners should be given opportunities to investigate trends in an area they are interested in, which again may be an area similar to their workplace. The assignment should include a range of data given to each learner, some of which may have been researched and collected during the delivery of this part of the unit content.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, M1, M2, D1</td>
<td>Health and Safety Legislation and Regulations</td>
<td>A written activity requiring learners to explain the key features of relevant legislation and regulations and describe the roles and responsibilities of management and the personnel involved.</td>
<td>A report containing written responses about the key features, responsibilities and management of health and safety legislation and regulations set in a relevant context for learners.</td>
</tr>
<tr>
<td>P4, P5, P6, P7, P8, P9, M3, M4, D2</td>
<td>Controlling Hazards and Risks in the Workplace</td>
<td>A practical activity to carry out a risk assessment, plus a written report and oral questioning.</td>
<td>A report, carried out under controlled conditions, describing the methods used to identify hazards and how hazards become risks. A written risk assessment of a typical working environment. A report with written responses that identify control measures and their justification. A record of observation by the tutor of the learner’s practical risk assessment.</td>
</tr>
<tr>
<td>P10, P11, M5, D3</td>
<td>Reporting and Recording Accidents and Incidents</td>
<td>A written activity requiring learners to explain principles of reporting accidents, incidents and near misses.</td>
<td>A report, carried out under controlled conditions, explaining reporting accidents, incidents and near misses.</td>
</tr>
</tbody>
</table>
Essential resources

Learners will require access to a wide range of safety literature. Ideally, the centre will be able to provide access to health and safety legislation and learning materials on DVD.

Indicative reading for learners

Textbooks


Websites

HSE www.hse.gov.uk
Unit 2: Engineering Principles

Level: 3
Unit type: Mandatory
Assessment type: External
Guided learning: 120

Unit introduction

Modern life depends on engineers to develop, support and control the products and systems that are all around us. For example, cars, heart rate monitors and manufacturing and transport systems. To make a contribution as an engineer, learners must draw on an important range of principles developed by early engineering scientists, such as Newton, Young, Faraday and Ohm. There is an increasing demand for ‘multi-skilled’ engineers who can apply principles from several engineering disciplines to develop solutions.

This unit will develop learners’ mathematical and physical scientific knowledge and understanding to enable them to solve problems set in an engineering context. They will explore and apply the algebraic and trigonometric mathematical methods required to solve engineering problems. The mechanical problems learners will encounter cover static, dynamic, fluids and thermodynamic systems. The electrical and electronic problems they will encounter cover static and direct current (DC) electricity, DC circuit theory and networks, magnetism, and single-phase alternating current theory. Learners will apply these engineering principles to solve problems involving more than one of these topic areas.

This unit is externally assessed. It sits at the heart of the qualification and gives learners a foundation to support them in any engineering technician role, an engineering apprenticeship or in higher education.

Summary of assessment

The unit will be assessed through one paper of 80 marks lasting two hours that will be set and marked by Pearson.

Learners will be assessed through a number of short- and long-answer problem-solving questions. Learners will need to explore and relate to the engineering contexts and data presented. Assessment will focus on learners’ ability to solve problems that require individual and combined application of mathematical techniques, and electrical, electronic and mechanical principles to solve engineering problems.

The assessment availability is twice a year in January and May/June. The first assessment availability is May/June 2017.

Sample assessment materials will be available to help centres prepare learners for assessment.
Assessment objectives

AO1 Recall basic engineering principles and mathematical methods and formulae
Command words: calculate, describe, explain
Marks: ranges from 1 to 5 marks

AO2 Perform mathematical procedures to solve engineering problems
Command words: calculate, find, solve
Marks: ranges from 1 to 10 marks

AO3 Demonstrate an understanding of electrical, electronic and mechanical principles to solve engineering problems
Command words: calculate, describe, draw, explain, find
Marks: ranges from 1 to 5 marks

AO4 Analyse information and systems to solve engineering problems
Command words: calculate, draw
Marks: ranges from 1 to 5 marks

AO5 Integrate and apply electrical, electronic and mechanical principles to develop an engineering solution
Command words: calculate, draw, explain
Marks: ranges from 1 to 10 marks
Essential content

A Algebraic and trigonometric mathematical methods

A1 Algebraic methods

- Indices and logarithms:
  - laws of indices: \( a^m \times a^n = a^{m+n} \), \( \frac{a^m}{a^n} = a^{m-n} \), \( (a^m)^n = a^{mn} \)
  - laws of logarithms: \( \log A + \log B = \log AB \), \( \log A^n = n \log A \), \( \log A - \log B = \log \frac{A}{B} \)
  - common logarithms (base 10), natural logarithms (base e).

- Application to problems involving exponential growth and decay.

- Linear equations and straight line graphs:
  - linear equations of the form \( y = mx + c \)
  - straight-line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line)
  - pair of simultaneous linear equations in two unknowns.

- Factorisation and quadratics:
  - multiply expressions in brackets by a number, symbol or by another expression in a bracket
  - extraction of a common factor \( ax + ay, a(x + 2) + b(x + 2) \)
  - grouping \( ax - ay + bx - by \)
  - quadratic expressions \( a^2 + 2ab + b^2 \)
  - roots of an equation, including quadratic equations with real roots by factorisation, and by the use of formula.

A2 Trigonometric methods

- Circular measure:
  - radian
  - conversion of degree measure to radian measure and vice versa
  - angular rotations (multiple number (n) of radians)
  - problems involving areas and angles measured in radians
  - length of arc of a circle \( s = r\theta \)
  - area of a sector \( A = \frac{1}{2} r^2\theta \)
• Triangular measurement:
  o functions (sine, cosine and tangent)
  o sine/cosine wave over one complete cycle
  o graph of \( \tan A \) as \( A \) varies from 0° and 360° confirming \( \tan A = \frac{\sin A}{\cos A} \)
  o values of the trigonometric ratios for angles between 0° and 360°
  o periodic properties of the trigonometric functions
  o the sine and cosine rule
  o application of vectors:
    – calculation of the phasor sum of two alternating currents
    – diagrammatic representation of vectors
    – resolution of forces/velocities.

• Mensuration:
  o standard formulae to solve surface areas and volumes of regular solids
    – volume of a cylinder \( V = \pi r^2h \)
    – total surface area of a cylinder \( TSA = 2\pi rh + 2\pi r^2 \)
    – volume of sphere \( V = \frac{4}{3}\pi r^3 \)
    – surface area of a sphere \( SA = 4\pi r^2 \)
    – volume of a cone \( V = \frac{1}{3}\pi r^2h \)
    – curved surface area of cone \( CSA = \pi rl \)

B Static engineering systems

B1 Static engineering systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems, involving:

• non-concurrent coplanar forces:
  o representation of forces using space and free body diagrams
  o moments
  o resolution of forces in perpendicular directions \( F_x = F\cos\theta, F_y = F\sin\theta \)
  o vector addition of forces – resultant, equilibrant and line of action
  o conditions for static equilibrium \( \Sigma F_x = 0, \Sigma F_y = 0, \Sigma M = 0 \)

• simply supported beams:
  o concentrated loads
  o uniformly distributed loads (UDL)

• reactions:
  o support reactions
  o pin reaction forces
  o roller reaction forces.
B2 Loaded components
Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- direct stress and strain: direct stress $\sigma = \frac{F}{A}$, direct strain $\varepsilon = \frac{\Delta L}{L}$
- shear stress and strain: shear stress $\tau = \frac{F}{A}$, shear strain $\gamma = \frac{a}{b}$
- tensile and shear strength
- elastic constants: modulus of elasticity $E = \frac{\sigma}{\varepsilon}$; modulus of rigidity $G = \frac{\tau}{\gamma}$

C Dynamic engineering systems
C1 Dynamic engineering systems
Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- kinetic parameters and principles:
  - displacement ($s$)
  - velocity – initial velocity ($u$), final velocity ($v$)
  - acceleration ($a$)
  - equations for linear motion with uniform acceleration
    $v = u + at$, $s = ut + \frac{1}{2} at^2$, $v^2 = u^2 + 2as$, $s = \frac{1}{2} (u + v)t$

- dynamic parameters and principles:
  - force
  - inertia
  - torque ($T$)
  - mechanical work $W = Fs$, mechanical power (average and instantaneous)
  - mechanical efficiency
  - energy: gravitational potential energy $PE = mgh$, kinetic energy $KE = \frac{1}{2} mv^2$
    - Newton’s Laws of Motion
    - principles of conservation of momentum
    - principles of conservation of energy

- angular parameters:
  - angular velocity ($\omega$)
  - centripetal acceleration $a = \omega^2 r = \frac{v^2}{r}$
  - uniform circular motion power $P = T\omega$
  - rotational kinetic energy $KE = \frac{1}{2} I\omega^2$
lifting machines, including inclined planes, scissor jacks, pulleys:
  o velocity ratio
  o mechanical advantage
  o effort and load motion
  o friction effects.

D Fluid and thermodynamic engineering systems

D1 Fluid systems
Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- submerged surfaces in fluid systems:
  o hydrostatic pressure and hydrostatic thrust on an immersed plane surface $F = \rho gAx$
  o centre of pressure of a rectangular retaining surface with one edge in the free surface of a liquid

- immersed bodies:
  o Archimedes’ principle
  o determination of density using floatation methods
  o relative density

- fluid flow in a gradually tapering pipe:
  o flow rate (volumetric and mass)
  o flow velocities (input and output)
  o input and output pipe diameters
  o incompressible fluid flow (continuity of volumetric flow $A_1v_1 = A_2v_2$ and mass flow $\rho A_1v_1 = \rho A_2v_2$)

D2 Thermodynamic systems
Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- heat transfer parameters in thermodynamic systems – temperature, pressure, mass, linear dimensions, time, thermal conductivity and surface finish

- heat transfer processes – conduction, convection and radiation

- linear expansivity; phases (solid, liquid and gas) $\Delta L = \alpha L \Delta T$

- heat transfer principles – specific heat capacity, sensible and latent heat transfer $Q = mc\Delta T$ and $Q = ml$

- thermal efficiency of heat transfer systems (heat engines and heat pumps)

- entropy and enthalpy $H = U + pV$, change of enthalpy to mechanical work (heat engines)
thermodynamic process equations
  - process parameters: absolute temperature and absolute pressure, volume, mass and density
  - gas laws – Boyle’s law \( pV = \text{constant} \), Charles’s law \( \frac{V}{T} = \text{constant} \)

\[ \frac{pV}{T} = \text{constant} \]

E Static and direct current electricity and circuits

E1 Static and direct current electricity

Recall, perform procedures, demonstrate an understanding of and analyse information and systems, in the context of electrical circuits (networks) and devices, including:

- conductance
- conventional current flow
- charge/electron flow \( I = \frac{q}{t} \)
- voltage
- Coulomb’s law \( F = \frac{q_1 q_2}{4\pi \varepsilon_0 r^2} \)
- factors affecting resistance, including conductor length, cross sectional area, resistivity, and temperature coefficient of resistance, \( R = \frac{pl}{A} \), \( \frac{\Delta R}{R_0} = \alpha \Delta T \)
- resistors, including function, fixed, variable, values
- electric field strength, including uniform electric fields \( E = \frac{F}{q}, \ E = \frac{V}{d} \)
- factors affecting capacitance, including plate spacing, plate area, permittivity \( C = \frac{\varepsilon A}{d} \)
- capacitors – typical capacitance values and construction, including plates, dielectric materials and strength, flux density, permittivity.

E2 Direct current circuit theory

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- Ohm’s law \( I = \frac{V}{R} \)
- power \( P = IV, P = \dot{E}V, P = \frac{V^2}{R} \)
- efficiency \( E = \frac{P_{\text{out}}}{P_{\text{in}}} \)
- Kirchhoff’s voltage and current laws \( V = V_1 + V_2 + V_3 \) or \( \Sigma PD = \Sigma IR, \)
  \( I = I_1 + I_2 + I_3 \)
- charge, voltage, capacitance and energy stored in capacitors $Q = CV$, $W = \frac{1}{2} CV^2$

- RC transients (capacitor/resistor), charge and discharge, including exponential growth and decay of voltage and current, and time constant $\tau = RC$

- Diodes, including forward and reverse bias characteristics:
  - forward mode applications, including rectification, clamping, circuit/component protection
  - reverse mode applications, including Zener diode for voltage regulation.

**E3 Direct current networks**

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- DC sources, including cell, battery, stabilised power supply, photovoltaic cell/array and internal resistance

- at least five resistors in series and parallel combinations

- $R_T = R_1 + R_2 + R_3$

- \[ \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]

- series resistors and diodes

- DC power source with at least two capacitors connected (series, parallel, combination).

**F Magnetism and electromagnetic induction**

**F1 Magnetism**

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

- magnetic field:
  - flux density $B \frac{\phi}{A}$
  - magnetomotive force (mmf) and field strength $(H)$, $F_m = NI$, $H = \frac{NI}{I}$
  - permeability $B = \mu_0 \mu_r$,
  - B/H curves and loops
  - ferromagnetic materials
  - reluctance $S = \frac{F_m}{\phi}$
  - magnetic screening
  - hysteresis
● electromagnetic induction and applications:
  o induced electromotive force (emf)
  o relationship between induced emf, magnetic field strength, number of conductor turns and rate of change of flux
  o relationship between number of turns, magnetic length, permeability, and inductance
  o eddy currents
  o principle of operation of electric motors and generators
  o self inductance, including inductance of a coil, energy stored in an inductor, induced emf:
    \[ L = \frac{N \phi}{I}, \quad W = \frac{1}{2} LI^2, \quad E = BLv, \quad E = -N \frac{d\phi}{dt} = -L \frac{dl}{dt} \]
  o mutual inductance (transformers – step up/down, primary and secondary current and voltage ratios):
    \[ \frac{V_1}{V_2} = \frac{N_1}{N_2} \]
  o application of Faraday’s and Lenz’s laws.

G Single-phase alternating current

G1 Single-phase alternating current theory
Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving:

● waveform characteristics:
  o sinusoidal and non-sinusoidal waveforms
  o amplitude, time period, frequency
  o instantaneous values:
    - peak/peak-to-peak
    - root mean square (RMS):
      \[ \text{RMS voltage} = \frac{\text{peak voltage}}{\sqrt{2}} \]
    - average values:
      \[ \text{average value} = \frac{2}{\pi} \times \text{maximum value} \]
    - form factor:
      \[ \text{form factor} = \frac{\text{RMS value}}{\text{average value}} \]
**AC principles:**

- determination of values using phasor and trigonometric representation of alternating quantities
- graphical and phasor addition of two sinusoidal voltages
- reactance and impedance of pure R, L and C components

\[ X_C = \frac{1}{2\pi fC}, \quad X_L = 2\pi fL \]

- total impedance of an inductor in series with a resistance \( z = \sqrt{X_L^2 + R^2} \)
- total impedance of a capacitor in series with a resistance \( z = \sqrt{X_C^2 + R^2} \)
- rectification, including half wave, full wave.
Grade descriptors

To achieve a grade a learner is expected to demonstrate these attributes across the essential content of the unit. The principle of best fit will apply in awarding grades.

Level 3 Pass

Learners are able to use and apply basic electrical, electronic, mechanical and mathematical principles to solve simple and familiar engineering and mathematical problems directly. They can provide responses showing understanding and analysis of basic and familiar engineering problems. They can interpret and analyse diagrams, graphical information and systems, using their knowledge and understanding to solve basic and familiar problems. They can select and implement appropriate basic procedures to provide solutions for given mathematical and engineering situations. They often use appropriate engineering and mathematical terminology and units. Learners can propose synoptic solutions to problems, drawing on their knowledge and understanding of basic electrical, electronic, mechanical and principles.

Level 3 Distinction

Learners are able to use and apply advanced electrical, electronic, mechanical and mathematical principles to solve complex and unfamiliar engineering and mathematical problems directly, indirectly and synoptically. They can provide balanced responses showing developed understanding and evaluation of complex familiar and unfamiliar engineering problems. They can interpret and evaluate diagrams, graphical information and systems, using their knowledge and understanding to solve complex familiar and unfamiliar problems. They can select and implement appropriate advanced procedures to provide justified and optimised solutions for given engineering and mathematical situations. They use appropriate and technically accurate engineering and mathematical terminology consistently. Learners can propose justified synoptic solutions to problems, drawing on their knowledge and understanding of electrical, electronic, mechanical and mathematical principles.
**Key terms typically used in assessment**

The following table shows the key terms that will be used consistently by Pearson in its assessments to ensure students are rewarded for demonstrating the necessary skills.

Please note: the list below will not necessarily be used in every paper/session and is provided for guidance only.

<table>
<thead>
<tr>
<th>Command or term</th>
<th>Definition</th>
</tr>
</thead>
</table>
| Calculate       | Learners judge the number or amount of something by using the information they already have, and add, subtract, multiply, or divide numbers.  
For example, ‘Calculate the reaction forces...’ |
| Describe        | Learners give a clear, objective account in their own words showing recall, and in some cases application, of the relevant features and information about a subject.  
For example, ‘Describe the process of heat transfer...’ |
| Draw            | Learners make a graphic representation of data by hand (as in a diagram).  
For example, ‘Draw a diagram to represent...’ |
| Explain         | Learners make something clear or easy to understand by describing or giving information about it.  
For example, ‘Explain one factor affecting...’ |
| Find            | Learners discover the facts or truth about something.  
For example, ‘Find the coordinates where...’ |
| Identify        | Learners recognise or establish as being a particular person or thing; verify the identity of.  
For example, ‘Identify the energy loss...’ |
| Label           | Learners affix a label to; mark with a label.  
For example, ‘Label the diagram to show...’ |
| Solve           | Learners find the answer or explanation to a problem.  
For example, ‘Solve the equation to...’ |
| State           | Learners declare definitely or specifically.  
For example, ‘State all three conditions for...’ |
Unit 3: Aircraft Flight Principles and Practice

Level: 3
Unit type: Mandatory
Assessment type: Internal
Guided learning: 60

Unit introduction

Large, modern passenger and transport aircraft can weigh more than 500,000 kg when they fly fully laden, yet this mass is lifted into the air with apparent ease. Light aircraft and military jet fighters are designed to be very manoeuvrable.

In this unit, learners will gain an understanding of the atmosphere in which aircraft fly and the mechanical and fluid principles associated with their flight. They will explore, through practical experimentation, the effects of airflow over aerodynamic surfaces, as well as how lift and drag are generated and how they interact during flight. Finally, learners will gain an understanding of the nature of stability and control, and the methods used to stabilise and control fixed-wing aircraft.

If learners want to work in the aircraft industry then understanding how aircraft lift is achieved and how aircraft are controlled and stabilised is essential. Studying this unit will help them progress to aircraft engineering technician roles in aircraft manufacture, maintenance, component overhaul and repair. It will also help learners progress to higher education to study aerodynamics or flight mechanics or, alternatively, assist with gaining entry to other aeronautical engineering degrees.

Learning outcomes

On completion of this unit a learner should:

1. Examine the atmospheric, mechanical and fluid principles affecting flight
2. Explore safely the lift and drag force generation and interaction that create aircraft flight
3. Investigate the nature and methods used to stabilise and control aircraft.
Unit content

1 Examine the atmospheric, mechanical and fluid principles affecting flight

The atmosphere, the International Standard Atmosphere (ISA) and its effect on flight

- The atmosphere:
  - composition of the air in the Earth’s atmosphere
  - layers of the Earth’s atmosphere to include the troposphere, stratosphere, mesosphere, thermosphere and exosphere
  - changes to the atmospheric air pressure, density and temperature
  - danger to flight due to severe atmospheric events, including:
    - lightning strike and the methods used to mitigate the effects
    - severe air turbulence and the possible effects on the aircraft
    - bird strike, hail strike
    - frost and ice accretion and their effects on aerodynamic performance.

- The International Standard Atmosphere (ISA):
  - the need for and functions of the ISA
  - define pressure (barometric, atmospheric, absolute), temperature (Kelvin, Centigrade, Fahrenheit, absolute), density, density ratio, dynamic viscosity, kinematic viscosity and sonic velocity
  - significance of and numerical values for the tropopause, temperature lapse rate, the temperature in the stratosphere
  - standard ISA values for the properties of air at ground level and their changes with altitude, to include pressure \( P \), density \( \rho \), temperature \( T \) dynamic (absolute) viscosity \( \mu \), kinematic viscosity \( \nu \) sonic velocity \( a \)
  - define the characteristic gas constant \( R \), the specific heat capacity of a gas at constant volume \( C_v \) and constant pressure \( C_p \), the ratio of specific heats \( \gamma = \frac{C_p}{C_v} \)
  - numerical values of \( R, C_v, C_p \) and \( \gamma \), for air, under standard conditions
  - the use of the ideal gas laws and characteristic gas equation in mass form \( pV = mRT \) to solve numerical problems on the density, pressure, mass and temperature of air, under differing conditions
  - the use of ISA tables to find changes in pressure, density, absolute viscosity, kinematic viscosity and sonic velocity, for varying altitudes
  - the density ratio \( \sigma \), and its relationship to the equivalent airspeed (EAS) and true airspeed (TAS) at varying altitudes
  - the use of the temperature lapse rate equation \( T = T_0 - Lh \), the sonic velocity approximation \( a = \sqrt{\frac{pRT}{\rho}} = 20.05\sqrt{T} \) and the density ratio, to determine properties of air at varying altitudes.
**Fluid flow and mechanical principles**

- Newton’s laws, including:
  - second law and its relationship to forces generated by aircraft acceleration
  - third law and its relationship to flight forces and to the generation of aircraft lift.
- Continuity equation for laminar constant incompressible steady flow, volume flow rate given by \( Q = A_1v_1 + A_2v_2 \) and for unsteady variable density flow, the mass flow rate is given by \( \dot{m} = \rho_1A_1v_1 = \rho_2A_2v_2 \)
- The Venturi principle and the nature of flow through a Venturi tube.
- The Bernoulli equation for incompressible steady flow:
  \[
  \rho g h_1 + \frac{1}{2} \rho v_1^2 + p_1 = \rho g h_2 + \frac{1}{2} \rho v_2^2 + p_2 \]
  also for total energy in a steady stream \( p + \frac{1}{2} \rho v^2 = c \)
- Centripetal and centrifugal accelerations where \( a = \frac{v^2}{r} \) and resulting forces
  \[
  F = \frac{mv^2}{r}
  \]
- Couples and turning moments where torque \( T = F \times r \)
- Principle of moments and balancing forces.
- Pressure measurement (mercury and aneroid barometer, manometer).

**Application of mechanical principles to aircraft flight**

- Flight forces:
  - position and equality of lift, weight, thrust and drag forces for straight and level flight
  - flight force couples (lift/weight and thrust/drag), action about centre of gravity (CG) and centre of pressure (CP)
  - balancing aerodynamic force from tailplane
  - using the principle of moments, determine balancing forces needed to maintain aircraft in static equilibrium.
- Flight forces in steady manoeuvres:
  - diagrammatic arrangement for system of forces and their components during gliding flight, diving flight, climbing flight and turning flight where
    \[
    L \sin \theta = \frac{mv^2}{r} \quad \text{and} \quad \tan \theta = \frac{v^2}{gr}
    \]
  - the definition and significance of load factors
  - analytical solution of flight force parameters, during flight manoeuvres
  - the effects of excessive manoeuvre loads on airframe structure, including pulled rivets, skin buckling, fuel and oil leakage, visual structural cracking, asymmetry of structure
methods used to prevent the loss of aircraft structural integrity in the event of overstressing damage, including: failsafe, safe life and on-condition structure, redundancy, radiation shields, planned maintenance, maintenance frequency

post-flight checks after flight through severe atmospheric events, including: examination of aircraft structure for damage, symmetry, examination for lightning and high intensity radiation field (HIRF) damage, instrument damage and degaussing, controls freedom of movement.

2 Explore safely the lift and drag force generation and interaction that create aircraft flight

The nature and effects of subsonic airflow over aerofoil sections

- The nature of subsonic airflow, including streamline, laminar and turbulent flow, compressibility effects at higher subsonic speeds.
- Aerofoil terminology, including aerofoil profile, camber, upper, lower and mean camber lines, chord line, leading and trailing edge, thickness/chord ratio or fineness ratio, angle of attack (AOA), angle of incidence (AOI).
- Viscosity effects and the boundary layer, including resistance to motion, velocity gradient, shear rate, boundary layer separation (transition point, separation point).
- Flow over aerofoil sections, including free stream, laminar and turbulent flow, relative airflow, up and down wash, stagnation point, separation.
- Pressure and flow changes at low, medium and high angles of attack and aerofoil stall effects.
- Airflow and aerodynamic shape, including aerofoils (flow over thin, medium, thick and symmetrical aerofoil sections), wings (aspect ratio, generation of tip vortices).

Aircraft lift, drag and their interaction

- Lift:
  - factors affecting lift, including aerofoil shape, lift coefficient, angle of attack, air density, airspeed and stall
  - centre of pressure and lift force
  - parameters and use of the lift equation, \[ L = C_l \frac{1}{2} \rho v^2 S \]
  - wing plan form designs for aircraft subject to low subsonic, high subsonic and transonic speed airflows
  - Effects that wing plan forms have on the generation of lift
  - use and types of wind tunnel apparatus, e.g. air blowers, lift and drag balances, open and closed section tunnels, flow visualisation equipment, airflow pressure and speed-measuring devices, aerofoil sections and whole aircraft models
  - measurement of lift forces using wind-tunnel apparatus
  - significance and interpretation of pressure plots for varying angles of attack and airspeed.
Drag:
- types of drag, including total, induced (trailing vortex), profile skin friction, profile form, interference
- factors affecting drag, including aerofoil shape, angle of attack, drag coefficient, airspeed, streamlining, damage to lift producing surfaces, ice and frost accretion
- drag reduction methods, including polished surfaces, fairings
- parameters and use of the drag equation $D = C_D \frac{1}{2} \rho v^2 S$
- significance and interpretation of profile, induced and total drag plots verses airspeed
- measurement of drag forces using wind tunnel apparatus
- theoretical determination of drag forces.

Lift and drag interaction:
- significance and interpretation of lift and drag plots
- polar plots of lift coefficient against drag coefficient and their interpretation
- plots of profile drag and induced drag (total drag) against airspeed
- minimum drag, the lift/drag ratio and aerofoil efficiency
- optimum angle of incidence (AOI).

Interpretation of aircraft model wind tunnel test results for lift, drag and pitching moment.

3 Investigate the nature and methods used to stabilise and control aircraft

Fixed-wing aircraft stability
- Nature of stability, including reaction to a disturbance for stable, unstable and naturally stable bodies, static and dynamic stability.
- Definitions for lateral, longitudinal and directional stability.
- Longitudinal static stability, including trim and stability, centre of pressure and aerodynamic centre movement, use of tailplane, CG position and limits for stability, effect of loading of stores and cargo.
- Lateral static stability, including yawing stability (yawing motion or weathercocking, use of fin, keel surface and wing dihedral), rolling stability (use of high wings and sweepback), use of anhedral.
- Nature of dynamic stability, including longitudinal stability (short period pitching oscillations and damping, phugoid motion and damping) and lateral stability (roll damping, spiral mode, Dutch roll and the effect of the fin and side slip on damping).
Fixed-wing aircraft control

- Purpose and operation of primary controls, including ailerons, elevators, rudder.
- Secondary controls including canards, stabilisers, elevons, tailerons and flaperons.
- Purpose and operation of control tabs, including trim, aerodynamic balance and anti-balance, balance panels, servo, spring, mass balance.
- Lift augmentation devices, purpose, operation and interaction, including flaps (plain, split, slotted, fowler, multi-slotted fowler, Krueger), slots, slats, vortex generators, wing fences, winglets.
- Purpose, operation and interaction of drag inducing devices, including spoilers (lift dump and roll), airbrakes.
- Control and stability interaction and aircraft design features for flight at transonic speed, including use of anhedral, sweepback, wing fences, delta wings, area ruling.
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
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<tbody>
<tr>
<td><strong>P1</strong></td>
<td>calculate the atmospheric changes due to varying altitudes and conditions, explaining the effects of these changes on aircraft flight</td>
<td><strong>M1</strong> analyse the dangers to flight caused by altitude and severe atmospheric events, identifying the nature of possible damage and appropriate mitigation methods</td>
<td><strong>D1</strong> evaluate, using language that is technically correct and of a high standard, how the structural design of an aircraft mitigates the impact of excessive flight forces and how post flight checks identify defects</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>explain the mechanical and fluid principles that enable flight</td>
<td><strong>M2</strong> analyse the forces that result from aircraft flight, identifying the nature of structural damage that may occur from the aircraft being subject to excessive loading</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>explain the nature of the loads and loading parameters imposed on the airframe during flight manoeuvres</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong></td>
<td>conduct experiments safely to determine the lift and drag forces produced from steady state air at two different speeds flowing over two different aerofoil sections set at three angles of attack</td>
<td><strong>M3</strong> conduct experiments accurately to determine the lift and drag forces produced from variable state and variable speed air flowing over different aerofoil sections set at three angles of attack</td>
<td><strong>D2</strong> evaluate the lift and drag forces and lift/drag ratios produced from variable state, variable speed air flowing over aerofoil sections under three angles of attack, comparing the results from safely conducted experiments and theoretical calculations</td>
</tr>
</tbody>
</table>
## Assessment and grading criteria

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<tr>
<td><strong>P5</strong> explain, using theoretical calculations and experimental results, the lift and drag forces produced from steady state air at two different speeds flowing over two different aerofoil sections set at three angles of attack</td>
<td><strong>M4</strong> analyse, using theoretical calculations and experimental results, the lift and drag forces and lift/drag ratios produced from variable state, variable speed air flowing over different aerofoil sections set at three angles of attack</td>
<td><strong>D3</strong> justify the methods used to control and stabilise modern aircraft that fly at high subsonic and transonic speeds</td>
</tr>
<tr>
<td><strong>P6</strong> explain the nature and operation of aircraft primary controls and secondary controls, lift augmentation and drag inducing devices</td>
<td><strong>M5</strong> analyse aircraft control and stabilisation methods, including how they interact</td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> explain the nature of stability and how aircraft are stabilised about their axes of rotation</td>
<td></td>
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</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will include in their evidence a series of calculations to determine the properties of atmospheric air at differing altitudes. For P2 and P3, explanations may be limited to the more obvious changes that occur with altitude, such as the drop in temperature, pressure and density of the air in the troposphere and their effect on lift forces. Learners’ explanations should connect these changes with one or two of the more obvious atmospheric events. For example, how a drop in temperature and precipitation conditions increases the risk of frost/ice accretion and the effects this may have on aerodynamic performance and controls handling.

Evidence should demonstrate the relationship between the Venturi principle, Bernoulli’s theorem, Newton’s second law and the generation of aircraft lift forces. Aerodynamic forces that occur during aircraft manoeuvres, including gliding, climbing, pulling out from a dive and turning flight, should be explained using vector diagrams.

Overall, the explanations should be logically structured, although basic in parts, and they may contain minor technical inaccuracies relating to engineering terminology, such as confusing dynamic viscosity with kinematic viscosity or using the term ‘transition point’, when they are really talking about the separation point. Also, the calculations may contain some minor arithmetic errors.

For P4 and P5, learners will safely and correctly set up and carry out a series of experiments and obtain results. A minimum of two experiments, each with a different aerofoil section, will be used to determine the effects on lift and drag across them at low, medium and high angles of attack. There may be some minor inaccuracies in the recording of the results, estimating lift and drag forces, and relating to the engineering terminology used.

Overall, learners’ explanations will be logically structured and clearly identify the changes to airflow over the aerofoil sections at different angles of attack up to the stall, explicitly commenting on their effect on lift and drag. The explanation of each experiment will include scale diagrams that are annotated with relevant figures, for example lift and drag forces. Theoretical calculations will also be included, but there may be minor numerical and diagrammatic errors.

For P6, learners will be clear in their explanations for the methods of primary control about the lateral, longitudinal and normal (directional) axes, together with the types and operation of secondary controls. For example, including lift augmentation and drag inducing devices.

A clear explanation of the nature of stability and for the methods used to stabilise conventional sub-sonic aircraft about their three axes of rotation should be given for P7.

Overall, the explanations should be logically structured, although basic in parts and they may contain minor technical inaccuracies relating to engineering terminology. These may include being unable to differentiate between the terms ‘neutral dynamic stability’ and ‘dynamic stability’ or using the term ‘fin’ when they mean ‘keel surface’ or using the term ‘leading edge flap’ when they clearly mean ‘leading edge slat’.

For M1 and M2, learners will provide evidence for each severe atmospheric condition of one area of damage that has been identified and the corresponding mitigation methods considered.
The quantitative analysis of forces that occur during all phases of flight should include taxiing, climbing, cruising, turning and diving manoeuvres. There should be clear evidence presented that identifies the nature, and considers the likely cause of, the structural damage that may occur from excessive loading during all phases of flight.

Overall, the analysis should be logically structured, technically accurate and easy to understand.

For M3 and M4, learners will conduct accurate experimental work, to include setting up the measuring equipment and recording results methodically. The practical work will also involve running the experiments under different airflow conditions, for example to conduct the experiments under steady streamlined and unsteady/turbulent airflows.

Overall, the analysis will be logically structured, technically accurate and easy to understand. Theoretical calculations of lift and drag forces and lift/drag ratios must be accurate and conform to accepted conventions.

For M5, learners will analyse the way in which aircraft are controlled and stabilised accurately, covering the interaction between aircraft controls, aircraft stabilising devices or both. For example, in the case of aircraft lateral role control, the reasons for and the interaction between the ailerons and drag inducing devices should be explained. Also, an explanation of lateral and longitudinal dynamic stability motion and the methods used to damp such motion should be included.

For D1, learners will produce evidence that includes a balanced evaluation of the structural design features and post-flight procedures used to ensure continuing airworthiness, including those problems presented by structural degradation. The evidence will include an accurate analysis of the aerodynamic forces acting on the aircraft during all phases of flight, as well as the dangers and atmospheric effects on flight through extreme weather events and their combined adverse effect on the aircraft during flight. In addition, there will be an evaluation of the structural design methods used to mitigate adverse effects and the post-flight procedures used to identify the defects resulting from adverse conditions.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer. For example, the evidence will be logically structured, use the correct technical engineering terms and will contain high quality written language, for example it will be grammatically clear.

For D2, learners will produce a balanced evaluation of at least two experiments undertaken with two different aerofoil sections and under different conditions, for example angles of attack. There should also be theoretical calculation of lift and drag forces and lift/drag ratios based on the airflow over at least two aerofoil sections.

The evaluation should include a comparison of the results obtained through safe experimentation and theoretical calculations, and explain why the variations occur, for example from experimental error and also from the limitations of the theoretical equations and the aerodynamic effects of wind tunnel testing when compared with real aircraft flight. Also, for example, there are the limitations with Bernoulli’s theorem, when used experimentally with both steady streamlined and unsteady/turbulent airflows.

Overall, the experimental evidence, for example a report, should be logically structured, use the correct technical engineering terms and will contain high-quality written language, for example they will be grammatically clear.
For D3, learners will comprehensively cover in their evidence the nature of aircraft stability, control and interaction of aircraft flying within the subsonic and transonic range. Well-reasoned arguments should justify the methods used to damp longitudinal phugoid motion as well as the use of sweepback, large fins, anhedral and area ruling stability and control methods.

Overall, the evidence will be logically structured and use the correct technical engineering terms.

**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
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</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, M1, M2, D1</td>
<td>Atmospheric Events and Mechanical and Fluid Principles Affecting Flight</td>
<td>An activity requiring learners to research the atmospheric events and mechanical and fluid principles that affect flight.</td>
<td>A report covering the atmosphere, the analysis of atmospheric parameters, mechanical and fluid principles and their effect on flight and continuing airworthiness.</td>
</tr>
<tr>
<td>P4, P5, M3, M4, D2</td>
<td>Lift and Drag Force Generation and Interaction</td>
<td>A series of experiments into lift and drag forces, with supporting documentation.</td>
<td>A portfolio of results gathered by experimentation when investigating airflow over aerofoil surfaces, and lift and drag generation and interaction. Supported by images, observation records, graphs and mathematical analysis.</td>
</tr>
<tr>
<td>Criteria covered</td>
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</tr>
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<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>P6, P7, M5, D3</td>
<td>Nature and Methods of Stabilising and Controlling Aircraft</td>
<td>An activity requiring learners to research the nature and methods used to stabilise and control aircraft.</td>
<td>A report covering the operation of flight control devices, the nature of stability and the implications and justification for the methods used for fixed-wing aircraft control and stabilisation.</td>
</tr>
</tbody>
</table>

**Essential resources**

For this unit, learners must have access to:

- mechanical laboratory equipment, such as centripetal acceleration/force apparatus, Venturi and Bernoulli apparatus, Newton’s cradle/Newtonian demonstrator, or similar apparatus to verify these principles
- flow visualisation apparatus, such as a smoke tunnel or a wind tunnel and prepared aerofoil sections with streamers
- an open- or closed-section wind tunnel, with lift and drag measurement equipment, speed and pressure measurement equipment. Please note that wind tunnels with manometers would be more suitable for experimental work than those with digital read-out equipment
- standard aerofoil sections, such as NACA 12 and others with known geometric parameters and pressure measurement plumbing
- workshop barometer and thermometer or other pressure and temperature measurement equipment.
Unit 4: Engineering Project

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 120

Unit introduction

In the modern world, engineers and technicians are often involved fully, or in part, with identifying problems and finding suitable solutions. These engineering problems may range from a very large project, such as designing and building a hydroelectric power station, to smaller projects, such as designing and producing a paper clip to keep notes secure. No matter how large or small, these problems need to be project managed in order to find engineered solutions. This unit will give learners opportunities to present their own solutions to engineering projects and should enable them to feel confident in carrying out project work in their chosen engineering discipline at the technician level.

The unit aims to integrate the knowledge and skills learners have gained throughout their programme of study into a major piece of work that reflects the type of performance expected of an engineering technician. The project is intended to develop learners’ abilities to identify and plan a course of action and follow this through to produce a viable solution/outcome to an agreed specification and timescale.

The end result of the project could be an engineering product, device, service or process or a modification to an existing process or product. As in the real world, the outcome of the project and its presentation are very important, although this project is also about developing the process skills necessary to carry out the project. Throughout the project learners will need to apply the technical skills developed in the other units in the qualification.

Learning outcomes

On completion of this unit a learner should:

1. Be able to keep records, specify a project, agree procedures and choose a solution
2. Be able to plan and monitor a project
3. Be able to implement the project plan within agreed procedures
4. Be able to present the project outcome.
Unit content

1 Be able to keep records, specify a project, agree procedures and choose a solution

*Project records*: written, e.g. notes, sketches, drawings; plans and modified plans; targets (setting, monitoring); use of planning tools, e.g. paper based, electronic; recording initial concepts, e.g. lists, notes, mind mapping, flow diagrams, sketches

*Initial concepts*: setting limits, e.g. time, cost, feasibility, need; value–cost–benefit analysis; generating ideas, e.g. group discussion, brainstorming, mind mapping; research techniques; lines of communication

*Specification*: type of project, e.g. product design, plant layout/maintenance, production methods or similar engineering-related topics; technical information, e.g. functionality, reliability, operational conditions, process capability, scale of operation, size, capacity, cost, style, ergonomics, present and future trends; health and safety issues; environmental and sustainability issues; quality standards and legislation; timescales; physical and human resource implications

*Procedures*: roles and responsibilities, e.g. decision making, budget planning and control; reporting methods; resource allocation and limits

*Techniques*: comparison methods, e.g. statistical, graphical, quality and resource requirements/limitations, process capability, fitness-for-purpose; analysis, e.g. cost–benefit, feasibility

2 Be able to plan and monitor a project

*Planning*: long-term planning, e.g. planners, charts and scheduling techniques (flow charts, Gantt charts, critical path methods, software packages); setting priorities; useful resource information, e.g. human and physical

*Monitoring*: monitor and record achievement, e.g. use of logbook and/or diary for record keeping (names, addresses, telephone numbers, meeting dates, email and other correspondence lists); use of logbook, e.g. for recording and analysing data or performance records, modifying/updating charts/planners, recording project goals and milestones, initial concepts, project solution technical decisions and information

3 Be able to implement the project plan within agreed procedures

*Implement*: proper use of resources, e.g. equipment, tools, materials, within agreed timescale, use of appropriate techniques for generating solutions, adapting project plan where appropriate, maintaining appropriate records

*Checking solutions*: use of evaluative and analytical techniques, e.g. graphs, matrix methods, statistics, Gantt charts, sequencing, scheduling, critical path methods, computer software packages
4 Be able to present the project outcome

*Presentation:* deliver a presentation to a small group, e.g. audience including known (peer group, tutors) and unknown (actual or simulated customer or client) participants; use of preparation techniques, presentation styles and techniques; preparation and use of visual aids, e.g. overhead transparencies, software packages and projectors, charts, models, video/DVD clips

*Project report:* logbook/diary record of all events; written technical report including relevant drawings/ circuit diagrams, sketches, charts, graphs etc. appropriate to the project solution; use of information and communication technology (ICT) as appropriate to present findings, e.g. computer-aided design (CAD), desktop publishing (DTP), spreadsheets, databases, word processing
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td><strong>P1</strong></td>
<td>prepare and maintain project records from initial concepts through to solutions that take account of and record changing situations</td>
<td><strong>M1</strong> maintain detailed, concurrent records throughout the project that clearly show progress made and difficulties experienced</td>
<td><strong>D1</strong> independently manage the project development process, seeking support and guidance where necessary</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>prepare a project specification</td>
<td><strong>M2</strong> use a wide range of techniques and selection criteria to justify the chosen option</td>
<td><strong>D2</strong> evaluate the whole project development process, making recommendations for improvements.</td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>agree and prepare the procedures that will be followed when implementing the project</td>
<td><strong>M3</strong> evaluate the project solution and suggest improvements</td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong></td>
<td>use appropriate techniques to evaluate three potential solutions and select the best option for development</td>
<td><strong>M4</strong> present coherent and well-structured development records and final project report.</td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong></td>
<td>outline the project solution and plan its implementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong></td>
<td>monitor and record achievement over the life cycle of the project</td>
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<td></td>
</tr>
<tr>
<td><strong>P7</strong></td>
<td>implement the plan and produce the project solution</td>
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### Assessment and grading criteria

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<td>P8</td>
<td>check the solution conforms to the project specification</td>
<td></td>
</tr>
<tr>
<td>P9</td>
<td>prepare and deliver a presentation to a small group, outlining the project specification and proposed solution</td>
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</tr>
<tr>
<td>P10</td>
<td>present a written project report.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment of this unit will be based primarily on the learner’s logbook/diary, other evidence of the work carried out and the processes adopted. The learner’s specification document, presentation and technical project report will also be used.

It should be noted that the logbook/diary is intended to be a working document and should contain the learner’s notes and records as they are made at the time. It does not need to be a well-presented/neat document, but should be an effective tool to capture events and information as and when they happen and provide a useful source of reference for the learner when preparing their presentation and final written report. The tutor/project supervisor could also annotate the logbook/diary to indicate and record their observations and interactions with the learner, for example use of ICT, the logical formulation of ideas, use of technical knowledge, analysis and the outcomes/recommendations from these meetings.

Learners will need to include, possibly as an annexe (under separate cover) to the technical report, their own sketches, drawings/circuit diagrams, notes, lists, charts, raw calculations etc. to support their project report findings. Appropriate methods of presentation and management of the total evidence package should be discussed and used by the learner.

Learners may well be working closely with their own company/employer on their project and may be required to adopt the company’s own ‘house style’ for the presentation of the report. This would of course be acceptable, since it will be in line with standard industry practice and report writing protocols, and because it is the content of the report (i.e. its technical information, logical presentation methods and coherence) that is assessed, not its style.

Care should be taken to identify learners who may be genuinely terrified of standing in front of a group to make a presentation. The experience of making such a presentation is valuable and is recommended. However, as a minimum, learners only have to make an informal presentation to one or two people (which would reflect the typical minimum required in employment at this level) to achieve the unit.

As many of the activities undertaken by learners will be practical and skills-based, it is important to think about the method of capturing and presenting such evidence for assessment purposes. Often, witness testimony or records of tutor observation will be necessary. Copies of these will need to be placed in the final portfolio of evidence.

In order to achieve P1, learners will need to prepare and maintain project records from initial concepts through to solutions that take account of and record changing situations. Evidence could be collected by tutors from the learner’s logbook. It is suggested that learners prepare and submit a written project specification for scrutiny in order to provide evidence for the achievement of P2 (i.e. that they have produced a specification to an acceptable standard). As part of the project specification, learners could also include written evidence for the procedures (P3) that they have agreed to follow, after discussion with their tutor, when implementing their project solution. Particular emphasis should be placed on ensuring that learners consider budgetary constraints and resource/time limitations. Evidence for the achievement of P4, concerning the evaluation of potential solutions and the techniques used to select the best option, might best be obtained from scrutiny of the learner’s logbook, or again form part of the written project specification/interim report.
To achieve learning outcome 2, learners will need to outline their chosen project solution and plan for its implementation (P5), in addition to monitoring and recording achievement over the life cycle of the project (P6). Evidence of achievement will again be through the logbook. Tutors may also wish to record some of this performance as an observation record or use witness statements. The observations might well take place when learners are using computer-aided or manual planning tools in the learning centre. Additional evidence for P6 might come from the annotation of planning documentation or plans in the learner’s logbook, that show the changing situations.

Learning outcome 3 is concerned primarily with the implementation of the project solution while adhering to agreed procedures (P7) and checking throughout the implementation phase that the solution produced conforms with the project specification (P8). The type of project chosen by the learner will, to a degree, dictate the methods used to provide evidence of achievement. Learners who are engaged on design/build or physical testing/modification type projects on a system or component, will be spending most of their project implementation phase in workshops and/or laboratories. Therefore, tutors will need evidence from observation records and from the physical solution itself. Evidence of achievement of P7 for those learners engaged in the production of a modified procedure/service, will provide evidence of achievement via their logbook records, presentation and final written report.

No matter what type of project learners choose, the primary source of evidence for achievement of P8 is likely to be the learner’s logbook, where comparisons can be made with the agreed procedures to see whether or not learners abided by these procedures when producing their project solution.

In order to meet learning outcome 4, learners will need to prepare and deliver a presentation outlining their project specification and proposed solution to a small group (P9) and present a written project report with supporting documentation (P10). Evidence for P9 will be obtained from a combination of hard copies of the presentation, such as handouts, slides etc. and witness statements, together with the results of observation records from those present. The evidence for the achievement of P10 will come from the written report itself. Clear guidelines as to what is expected need to be given to learners well before the submission of their report.

To achieve M1, learners need to work with greater autonomy and will have produced, and kept to, a workable plan. This will be demonstrated by their ability to maintain records throughout the project that are detailed, concurrent and clearly show progress made and the difficulties experienced. For M2, learners will need to arrive at their project choice having used a wide range of techniques and, from the use of them, be able to justify their chosen option. The range of techniques used will need to show both statistical and graphical comparison methods for the potential solutions. Evidence will come from the learner’s logbook and/or from the submitted written specification/interim report, (as was the case for achievement of P3).

Evidence for the achievement of M3 will come from observation records (particularly for design and build type solutions), scrutiny of logbook records and from the learner’s reflections, written in the final report. It is expected that having evaluated their solution against the specification and/or from field evaluation and customer feedback, learners will then be able to suggest improvements that genuinely enhance the value of their project solution. Learners will have to present coherent and well-structured development records and final project report to achieve M4. The report structure is expected to adhere to standard technical report writing protocols, in order to achieve the criteria. The development records are
likely to be included, as part of the learner’s logbook and this should be submitted for final scrutiny, at the same time as the report.

To achieve a distinction, learners will work consistently towards a successful outcome and in doing so they will independently manage the project development process, seeking support and guidance where necessary (D1). They will reflect on their work throughout the project. Through this, they will evaluate the whole of the project development process and provide suggestions as to what they would have done differently to make improvements (D2). The evidence for both criteria is likely to come from the logbook and portfolio notes with the addition of witness statements and observation records for D1 and a separate written statement or statement in the final report, clearly evaluating the project making recommendations for improvements for D2.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, M1</td>
<td>Prepare and Maintain Project Records</td>
<td>Tutor to scrutinise learner’s project records and/or take account of observation records or witness testimony.</td>
<td>Through scrutiny of learner’s logbook, observation records and/or witness testimony. Detailed and concurrent records need to be demonstrated to achieve M1.</td>
</tr>
<tr>
<td>P2, P3, P4, M2</td>
<td>Project Specification and Selection of Best Project Option</td>
<td>Tutor to consider submitted work and scrutinise learner records and/or take account of observation records or witness testimony.</td>
<td>Marked submission of project specification to acceptable standard, including written procedures to be adopted and evidence for the evaluation of solution. A wide range of statistical and graphical comparison methods demonstrated to meet criterion M2.</td>
</tr>
<tr>
<td>P5, P6</td>
<td>Production of Project Plan and Monitor Project Over its Life Cycle</td>
<td>Tutor to scrutinise project records and take account of observation records or witness testimony.</td>
<td>Scrutinise learner’s long-term plans and logbook, identify and sanction achievement and changes made to plan, over the life of the project.</td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>P7, P8, M3</td>
<td>Implement the Project and Produce the Project Solution</td>
<td>Tutor to observe learner progress in the implementation of project plan and in the production of project solution.</td>
<td>Through scrutiny of learner’s logbooks and observation records for implementation of project solution and written/observational evidence for evaluation of solution in order to meet M3 criterion.</td>
</tr>
<tr>
<td>P9, P10, M4</td>
<td>Presenting the Project Outcome</td>
<td>Observation of oral presentation and consideration of written report and other project records and deliverables.</td>
<td>Through observation records and written oral presentation material and the marking of the final written report and consideration of all other project deliverables. Identification of well-structured and coherent development records and final report in order to meet M4.</td>
</tr>
<tr>
<td>D1, D2</td>
<td>Independently Manage and Critically Evaluate the Whole Project</td>
<td>Tutor/supervisor observation records or independent witness statements and take account of learners project records and written submissions.</td>
<td>Scrutinise learner’s logbook and take account of observation records (D1) and mark written submission (D2).</td>
</tr>
</tbody>
</table>
Essential resources

For this unit, learners will need access to a wide variety of physical resources, dependent on the type of project they pursue. Many of these resources are detailed in the other units in the qualification. There is also a need to provide some form of access to audio-visual aids, as well as access to libraries and computer-aided learning centres. Learners may also require access to workshops, laboratories and specialist catalogues and other documentation. Centres should subscribe to engineering journals and stock other useful literature, specific to the branches of engineering being covered.

Indicative reading for learners

Textbooks


Unit 5: Communications for Engineering Technicians

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

The ability to communicate effectively is an essential skill in all aspects of life. The usual methods of communication – speaking, reading and writing – receive considerable attention and learning time during all stages of education. For engineers, these skills are of no less importance, but there are further complications with the need to also convey technical information such as scale, perspective and standards of working.

The drive towards greater use of information and communication technology (ICT) is very much a part of modern life and this again is certainly the case for engineering. The engineering industry is in the front line of working towards paperless communication methods, for example the electronic transfer of data from the concept designer straight to the point of manufacture.

This unit will give a foundation for employment in a wide range of engineering disciplines (for example manufacturing, maintenance, communications technology), in addition to giving a foundation for further study. It aims to develop learners’ ability to communicate using a diverse range of methods. These include visual methods, such as drawing and sketching, and computer-based methods, such as two-dimensional (2D) computer-aided design (CAD) and graphical illustration packages. It will also develop learners’ ability to write and speak in a framework of technology-based activities, using relevant and accurate technical language appropriate to the task and the audience.

The unit will introduce learners to a variety of skills and techniques to obtain and use information, for example the presentation of technical reports, business and technical data and the use of visual aids for presentations. Learners will consider how to make best use of ICT in technological settings that are relevant to their programme of study or area of employment.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information
2. Be able to use verbal and written communication skills in engineering settings
3. Be able to obtain and use engineering information
4. Be able to use information and communication technology (ICT) to present information in engineering settings.
Unit content

1 Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information

*Interpret:* obtain information and describe features, e.g. component features, dimensions and tolerances, surface finish; identify manufacturing/assembly/process instructions, e.g. cutting lists, assembly arrangements, plant/process layout or operating procedures, electrical/electronic/communication circuit requirements; graphical information used to aid understanding of written or verbal communication, e.g. illustrations, technical diagrams, sketches

*Engineering sketches/circuit/network diagrams:* freehand sketches of engineering arrangements using 2D and 3D techniques, e.g. components, engineering plant or equipment layout, designs or installations; electrical/electronic circuit diagrams, system/network diagrams; use of common drawing/circuit/network diagram conventions and standards, e.g. layout and presentation, line types, hatching, dimensions and tolerances, surface finish, symbols, parts lists, circuit/component symbols, use of appropriate standards (British (BSI), International (ISO))

2 Be able to use verbal and written communication skills in engineering settings

*Written work:* note taking, e.g. lists, mind mapping/flow diagrams; writing style, e.g. business letter, memo writing, report styles and format, email, fax; proofreading and amending text; use of diary/logbook for planning and prioritising work schedules; graphical presentation techniques, e.g. use of graphs, charts and diagrams

*Verbal methods:* speaking, e.g. with peers, supervisors, use of appropriate technical language, tone and manner; listening, e.g. use of paraphrasing and note taking to clarify meaning; impact and use of body language in verbal communication

3 Be able to obtain and use engineering information

*Information sources:* non-computer-based sources, e.g. books, technical reports, institute and trade journals, data sheets and test/experimental results data, manufacturers’ catalogues; computer-based sources, e.g. inter/intranet, DVD-based information (manuals, data, analytical software, manufacturers’ catalogues), spreadsheets, databases

*Use of information:* e.g. for the solution of engineering problems, for product/service/topic research, gathering data or material to support own work, checking validity of own work/findings
4 Be able to use information and communication technology (ICT) to present information in engineering settings

Software packages: word processing; drawing, e.g. 2D CAD, graphics package; data handling and processing e.g. database, spreadsheet, presentation package, simulation package such as electrical/electronic circuits, plant/process systems; communication, e.g. email, fax, inter/intranet, video conferencing, optical and speech recognition system

Hardware devices: computer system, e.g. personal computer, network, plant/process control system; input/output devices, e.g. keyboard, scanner, optical/speech recognition device, printer, plotter

Present information: report that includes written and technical data, e.g. letters, memos, technical product/service specification, fax/email, tabulated test data, graphical data; visual presentation, e.g. overhead transparencies, charts, computer-based presentations (PowerPoint)
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To achieve a pass grade</strong></td>
</tr>
<tr>
<td>the evidence must show that the learner is able to:</td>
</tr>
<tr>
<td><strong>P1</strong> interpret an engineering drawing/circuit/network diagram</td>
</tr>
<tr>
<td><strong>P2</strong> produce an engineering sketch/circuit/network diagram</td>
</tr>
<tr>
<td><strong>P3</strong> use appropriate standards, symbols and conventions in an engineering sketch/circuit/network diagram</td>
</tr>
<tr>
<td><strong>P4</strong> communicate information effectively in written work</td>
</tr>
<tr>
<td><strong>P5</strong> communicate information effectively using verbal methods</td>
</tr>
<tr>
<td><strong>P6</strong> use appropriate information sources to solve an engineering task</td>
</tr>
<tr>
<td><strong>P7</strong> use appropriate ICT software packages and hardware devices to present information.</td>
</tr>
</tbody>
</table>
Effective guidance for tutors

Assessment

Unit 4: Engineering Project could provide an excellent vehicle for an integrated approach to the assessment of this unit. The project work undertaken will require learners to use communication skills to interpret information, prepare sketches and drawings, give presentations, develop and use data sheets, produce technical reports and letters etc. Other units in the programme could also be used to provide effective and relevant learning and formative or even summative assessment opportunities. However, using Unit 4: Engineering Project for assessment has the advantage of providing a structured focus for the work and a coherent source of relevant evidence.

To achieve a pass, learners should interpret (P1) and produce (P2) engineering sketches (2D and 3D)/circuit/network diagrams and sketches. This will need to be at a level sufficient for them to understand and communicate technical information. This must include identification and use of appropriate standards, symbols and conventions (P3). The use of sketches/circuit/network diagrams in the criteria P1 and P2 is intended to indicate a choice that will depend on the focus of the learning programme in which this unit is being delivered. For example, a learner on a mechanical programme is likely to choose to interpret and produce sketches of components, while a learner studying electrical/electronics is more likely to interpret and produce circuit diagrams.

A single assessment activity could be used to link and capture evidence for the first three pass criteria (P1, P2 and P3). The activity would need to ensure that learners had an opportunity to obtain information, describe features, identify instructions and make use of graphical information (P1). For example, the task could be to work with written operating instructions that include supporting diagrams and sketches (2D and 3D). From the initial investigation, the activity could then require learners to produce their own drawing and sketches (P2). The criterion P3 would need to be applied to both the interpretation (identify) and the production (use) of their working document.

Learners should use written (P4) and verbal (P5) communication methods. The written work must include evidence of note taking, the ability to use a specific writing style, proofread and amend text, use a diary/logbook and use graphical presentation techniques. It might be that all of these will not necessarily occur in a single task/activity. If not, it would be acceptable for a number of pieces of assessment evidence to be brought together to meet this criterion.

The use of verbal methods (P5) will require learners to demonstrate speaking and listening skills and an understanding of the impact and use of appropriate body language. The evidence for this should come from one task/activity so that all three aspects are being dealt with at the same time. This could be a meeting with either peers and/or a supervisor, or could come from a presentation delivered by the learner to a group.

It would be important to ensure that the learner had to take questions from the group to enable the tutor to capture evidence of their ability to listen. The evidence for this criterion is likely to be a tutor observation record or witness statement.
P6 can be assessed using any structured activity that requires learners to identify and use appropriate information sources to solve an engineering task. It is essential that the information comes from both computer-based and non-computer-based sources. The evidence for this criterion could be as simple as suitably referenced work (a bibliography would not be sufficient). However, it would be preferable to have a record of the original source and a hard copy, annotated to show the information identified and used for the task (or at least an example of this process).

The final pass criterion (P7) could be assessed using any relevant tasks that require learners to select and use appropriate ICT software packages and hardware devices to present information. It is essential that the task or tasks chosen for this criterion give learners opportunities to use appropriate software to cover all the ICT applications listed in the content, i.e. there must be evidence of learners’ selection and use of ICT for word processing, drawing, data handling and communication (such as email). The requirement for hardware devices is limited to the choice and use of a computer system and relevant input/output devices that would be needed for the task carried out. It is expected that the range of information presented using ICT will include a technical report and visual presentation material, for example overhead transparencies, chart, computer-based presentation (PowerPoint).

As already suggested, Unit 4: Engineering Project could provide an excellent vehicle for assessment of this unit since it could provide a central focus and therefore a source of coherent assessment evidence. Any alternatives should try to establish a similar coherence and avoid fragmentation of the pass criteria wherever possible.

To achieve a merit, learners should evaluate a written communication method and identify ways in which it could be improved (M1). This could be learners’ own written work or the written work of someone else. The important aspect of this criterion is the learners’ ability to use their skills and understanding of communication methods to appraise the work and identify enhancements.

In addition, learners will need to review the information sources obtained to solve an engineering task and explain why some sources have been used but others rejected (M2). This criterion is about reflection and the need to carefully consider, measure and express the value (or not) of other people’s work as a source of information. Learners need to have identified both non-computer-based and computer-based information sources for P6 and it is this material that they should be reviewing for M2. Achievement might well be implicit if the task undertaken for P6 has reached a satisfactory solution. However, the expected evidence for this criterion would be a copy of the source material used, suitably annotated to explain its value or why it has been rejected.

Finally, merit criterion M3 requires learners to evaluate an ICT software package and its tools for the preparation and presentation of information. This criterion requires learners to have taken time to reflect on their work and consider the use of software tools available (for example good/consistent use of font size/colour, alignment of text, positioning on the page, use of automated labels, legends and titles for graphs).

To achieve a distinction, learners should justify their choice of a specific communication method and the reasons for not using a possible alternative (D1). This could be any communication method that the learner has chosen to use (for example drawings, written, verbal).
It does require learners to have considered at least one possible alternative during the initial selection of the method used. Learners will therefore need to be briefed to collect evidence of this selection process, which might otherwise be lost or ignored (for example initial outlines/drafts, notes of any consultation with others on method to be employed). The key issue for this criterion is learners’ ability to reflect and evaluate. At pass level, learners will have shown their ability to communicate information effectively and, at merit, to be critical of the content of their own or other people’s work. At distinction level, they should be critical of the choice of communication method used.

D2 requires learners to evaluate their use of an ICT presentation method and identify an alternative approach. This criterion is about the method of presentation and not the method of communication. It also has a direct link with related pass (P7) and merit (M3) criteria. At pass, learners need to use ICT to present information and, at merit, to evaluate the effectiveness of the presentation.

For D2, learners should consider the overall approach taken. For example, could a word-processed technical report have been presented using a computer-based presentation package, such as PowerPoint, including automated routines and animated graphics or video clips? The evidence for this is likely to be a written evaluation. A rough outline illustrating their identified alternative approach or even a small section of the original reworked using an alternative approach could be used to support the written evaluation.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2 and P3</td>
<td>Communicating Technical Information</td>
<td>Explore a product/circuit/network and interpret and prepare appropriate engineering sketches/circuit/network diagrams.</td>
<td>A written report providing the learner’s interpretation of the information and features found. Engineering sketches/circuit/network diagram prepared by the learner.</td>
</tr>
<tr>
<td>P4, P5, M1 and D1</td>
<td>Writing, Talking and Listening</td>
<td>A series of tasks focused on written work and verbal communication methods.</td>
<td>A portfolio of evidence containing examples of note taking, writing styles, use of diary/logbook and use of graphical presentation techniques. Tutor observation of speaking, listening and use of body language.</td>
</tr>
<tr>
<td>P6, M2</td>
<td>Finding and Using Information</td>
<td>Solving an engineering problem through research and use of information.</td>
<td>A written report with suitable reference to the range of sources found and used, including non-computer-based and computer-based resources.</td>
</tr>
<tr>
<td>P7, M3, D2</td>
<td>The Use of ICT in Engineering</td>
<td>Presenting engineering information using ICT.</td>
<td>A written report on the selection and use of computer hardware devices. A portfolio of evidence of the use of word processing, drawing, data handling and communication software packages to present engineering information.</td>
</tr>
</tbody>
</table>
Essential resources

Access to information and communication technology resources (including the internet) is essential for the delivery of this unit, as is a well-stocked source of reference material.

Learners should be given a variety of sample written materials (letters, memos, technical reports, data sheets, catalogues) and sketches. Centres will need to provide access to appropriate presentation and graphics software (for example Microsoft PowerPoint, Visio), spreadsheet/database software (for example Microsoft Excel/Access) and computer hardware (for example scanners, printers, optical character recognition and speech recognition software, barcode readers).

Indicative reading for learners

Textbooks


Unit 6: Calculus to Solve Engineering Problems

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Many of the products, components and systems that we use have been subject to a rigorous design process that will have involved the use of calculations including mathematical calculus. During the design stage, it is important to be able to predict how a product will perform in service, for example the handling characteristics of a car or the power output from an electrical power supply. Also, investing time and resources in setting up manufacturing machinery and supply chains is very expensive – working with formulae and numbers on paper or using a computer involves a lot less cost and allows engineers to determine optimal (or near-optimal) solutions.

In this unit, learners will investigate how to apply differential and integral calculus methods to solve engineering problems. They will learn about the rules and procedures of calculus mathematics to obtain solutions to a variety of engineering problems. Learners will solve a complex problem from their specialist area of study and perhaps from a local organisation, by breaking it down into a series of linked manageable steps. Each step will be solved using calculus methods learned through investigation and practice. These mathematical skills are transferable and will be used to support learners’ study of other topics in this qualification, for example in mechanical principles and electrical systems.

As an engineer, learners need to understand and develop the skills required to solve problems using calculus and other mathematical procedures. This unit will prepare them well for progressing to higher education to study for an engineering degree or a Higher National Diploma (HND). It will also help prepare learners for an apprenticeship or for employment in a range of engineering disciplines as a technician, and will help them work with professional engineers as part of a team working on cutting-edge products and systems.

Learning outcomes

On completion of this unit a learner should:

1. Examine how differential calculus can be used to solve engineering problems
2. Examine how integral calculus can be used to solve engineering problems
3. Investigate the application of calculus to solve a defined specialist engineering problem.
Unit content

1 Examine how differential calculus can be used to solve engineering problems

Functions, rate of change, gradient

- Function notation, e.g. $y = f(x)$, $s = f(t)$, $Q = f(t)$
- Types of functions: polynomial, trigonometric (sine, cosine), logarithmic and exponential.
- Routine functions are differentiated in one step without the need for manipulation, using standard calculus methods and/or are not applied to an engineering context, including:
  - polynomial, e.g. $s = 5t^2 - 3t + 4$
  - trigonometric (sine, cosine), e.g. $y = \sin^24x$
  - logarithmic, e.g. $v = 8\log_4(5x)$
  - exponential, e.g. $y = 2e^{(3x+5)}$
- Non-routine functions are differentiated in more than one step requiring manipulation, using standard calculus methods and/or may be applied to an engineering context, including:
  - polynomial, e.g. $I = \frac{z+3}{5-4z}$
  - trigonometric (sine, cosine), e.g. $v = (\sin2\cos3t)$
  - logarithmic, e.g. $y = 5x^2\log_4(3x)$
  - exponential, e.g. $v = 5e^{3(2t^2 - 3)}$
- Expanding or simplifying polynomial functions.
- Rate of change of a function.
- Graphical representation of a function.
- Gradient of a function – graphically by tangent.
- Time-based functions, e.g. velocity, charge rate, energy transfer.

Methods of differentiation

- Gradient of a function.
- Small change in a quantity.
- Differentiation from first principles to produce the limiting value (derivative) of a simple power function, e.g. $y = 2x^2$
  - Leibniz notation \( \left( \frac{dy}{dx} \right) \) or representing the derivative of a function.
  - Engineering notation for the derivative, e.g. \( \left( \frac{dx}{dt} \right), \left( \frac{dQ}{dt} \right) \)
  - Independent variable and the coding method ‘with respect to’ (w.r.t.).
  - Differentiation by standard results ($y = ax^n$, where \( \frac{dy}{dx} = nax^{(n-1)} \))
The derivatives of algebraic (power), trigonometric (sine, cosine), logarithmic and exponential functions ($ax^n$, $\sin ax$, $\cos ax$, $\log_a(x)$, $e^{ax}$)

$$\frac{dy}{dx} = v \frac{du}{dx} + u \frac{dv}{dx}, \quad \frac{dy}{dx} = \left( v \frac{du}{dx} - u \frac{dv}{dx} \right) / v^2$$

Product and quotient rules:

Function of a function (chain rule) method.

Substitution method.

**Numerical value of a derivative**

Substitution of numerical values into the expression for the derivative.

Instantaneous gradient at a point on a curve.

Positive, negative and zero values for gradients.

Gradient values obtained analytically and graphically.

Engineering examples of rates of change, e.g. velocity/acceleration of a moving object, rate of charge/discharge of a capacitor, heat flow, radioactive decay, cutting tool life, charge/discharge rate for an air receiver, hydraulic flow rates.

**Second derivative and turning points**

Leibniz notation for the second derivative $\left( \frac{d^2y}{dx^2} \right)$

Second derivative of algebraic (polynomial) and trigonometric (sine, cosine) functions.

Turning points on a function.

Graphical representation of an algebraic function with two turning points, e.g. $y = x^3 - 5x^2 + 2x + 6$

Maximum (max) and minimum (min) turning points, inflection point.

Second derivative test for max/min points on a function.

Numerical value of the dependent variable at the max/min points of a function.

Engineering applications, e.g. maximising the volume of a container for a given surface area, minimising the cost of mass-producing components on a machine tool, resistance matching in electrical power circuits to achieve maximum power transfer.
2 Examine how integral calculus can be used to solve engineering problems

Integration as the reverse/inverse of differentiation

- Symbolic representation \( \int f(x) \, dx \)
- Algebraic expressions and the constant of integration.
- Types of functions: polynomial, trigonometric (sine, cosine), reciprocal and exponential.
- Routine functions are integrated in one step without the need for manipulation, using standard calculus methods and/or are not applied to an engineering context, including:
  - polynomial, e.g. \( \int (x^2 - 3x + 4) \, dx \)
  - trigonometric (sine, cosine), e.g. \( \int (\sin 5\theta - 3\cos 4\theta) \, d\theta \)
  - reciprocal, e.g. \( \int \left( \frac{3}{x} \right) \, dx \)
  - exponential, e.g. \( \int e^x \, dt \)
- Non-routine functions are integrated in more than one step requiring manipulation, using standard calculus methods and/or may be applied to an engineering context, including:
  - polynomial, e.g. \( \int x^2 (x^3 + 5)^2 \, dx \)
  - trigonometric (sine, cosine), e.g. \( \int \left( \frac{\cos \theta}{1 - \sin \theta} \right) \, d\theta \)
  - exponential, e.g. \( \int e^x \cos \theta \, dt \)
- Integration of common functions by standard results: \( ax^n \), \( \sin ax \), \( \cos ax \), \( \frac{1}{x} \), \( e^{ax} \)
- Indefinite integrals, constant of integration, initial conditions.
- Definite integrals – limits and square bracket notation.
- Integration by substitution.
- Integration by parts.

Integration as a summing tool

- Area under a curve from first principles – strip theory (approximate area of the elemental strip = \( y \, dx \)).
- Area under a curve as a summation between the upper and lower limits applied to the function.
- Mean value and root mean square (RMS) value of periodic functions.
- Engineering applications, e.g. work done by force producing displacement of an object, distance travelled by a vehicle, mean and RMS values of waveforms in electrical circuits.
Numerical integration

- Trapezoidal rule, mid-ordinate rule, Simpson’s rule – comparison of methods in terms of their complexity and accuracy.
- Area under a curve obtained by integrating its function – comparison with the value obtained using Simpson’s method.
- Numerical integration using a spreadsheet.
- Engineering applications, e.g. determination of mechanical, electrical and thermal energy.

3 Investigate the application of calculus to the solution of a defined specialist engineering problem

Thinking methods

- Reductionism – considering a complex problem as the sum of its elements/parts or breaking a problem down into its parts.
- Synectics – creativity in mathematics, idea generating methods.
- Logical thinking – coherent and logical approach to solving a problem, e.g. Polya’s problem-solving method.

Mathematical modelling of engineering problems

- Analytical methods.
- Numerical methods.
- ‘What if’ repetitive calculation, ‘Goal Seek’.
- Benefits of using mathematical modelling, e.g. design viability, structural integrity of a product, accurate prediction of how a new product will perform in service, cost benefit of accurate simulation, e.g. in the design of aircraft.
- Engineering applications, e.g. mechanical design, stress analysis, performance calculation for an electronic or fluid-powered hydraulic circuit.

Problem specification and proposed solution

- Application of thinking methods to understand a given engineering problem.
- The use of mathematical modelling to devise a method to solve the given engineering problem.

Solution implementation

- The use of calculus and other appropriate mathematical methods to solve the given engineering problem.
- Reflection on the problem-solving process and the solution obtained, making refinements if necessary.
- Presentation of the solution to the given engineering problem.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong></td>
<td>find the first and second derivatives for each type of given routine function</td>
<td><strong>M1</strong> find accurately the graphical and analytical differential calculus solutions and, where appropriate, turning points for each type of given routine and non-routine function and compare the results</td>
<td><strong>D1</strong> evaluate, using technically correct language and a logical structure, the correct graphical and analytical differential calculus solutions for each type of given routine and non-routine function, explaining how the variables could be optimised in at least two functions</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>find, graphically and analytically, at least two gradients for each type of given routine function</td>
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<td></td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>find the turning points for given routine polynomial and trigonometric functions</td>
<td><strong>M2</strong> find accurately the integral calculus and numerical integration solutions for each type of given routine and non-routine function, and find the properties of periodic functions</td>
<td><strong>D2</strong> evaluate, using technically correct language and a logical structure, the correct integral calculus and numerical integration solutions for each type of given routine and non-routine functions, including at least two set in an engineering context</td>
</tr>
<tr>
<td><strong>P4</strong></td>
<td>find the indefinite integral for each type of given routine function</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong></td>
<td>find the numerical value of the definite integral for each type of given routine function</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong></td>
<td>find, using numerical integration and integral calculus, the area under curves for each type of given routine definitive function</td>
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<tr>
<td><strong>P7</strong> define a given engineering problem and present a proposal to solve it</td>
<td><strong>M3</strong> analyse an engineering problem, explaining the reasons for each element of the proposed solution</td>
<td><strong>D3</strong> critically analyse, using technically correct language and a logical structure, a complex engineering problem, synthesising and applying calculus and a mathematical model to generate an accurate solution.</td>
</tr>
<tr>
<td><strong>P8</strong> solve, using calculus methods and a mathematical model, a given engineering problem.</td>
<td><strong>M4</strong> solve accurately, using calculus methods and a mathematical model, a given engineering problem.</td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will apply the correct skills and methods when differentiating at least six given routine mathematical functions. Learners will correctly manipulate at least two polynomial, two trigonometric, one logarithmic and one exponential. Some functions will be sufficiently complex to enable apprentices to select and apply the correct method (product, quotient, function of a function and substitution) when producing first and second derivatives.

For P2, learners will demonstrate that they can find, graphically and analytically, at least two gradients for each type of function. For P3, for the polynomial and trigonometric functions, learners will calculate the turning points in the context of rates of change.

Overall, learners must demonstrate the correct use of method when differentiating functions and use the correct units. Minor arithmetic and scaling errors are acceptable. There will be evidence of simple checks to determine if numerical answers are 'reasonable'. Graphical presentation of functions and determination of their gradients can be done using a spreadsheet, provided that formulae are visible (printed out).

For P4, P5 and P6, learners will demonstrate mastery in the application of integral calculus methods to the solution of given problems using mathematical functions. Learners will correctly and efficiently manipulate eight routine and three non-routine functions.

Learners must present reasoned arguments when evaluating the use of analytical and numerical integration methods on at least two non-routine functions, for example, finding work done by expressing parameters as a definite integral and then repeating the operation using Simpson's rule.

Overall, the evidence will be logically structured, easy to understand by a third party with a mathematical background, who may or may not be an engineer, and there will be correct use of mathematical terminology. Small and large numerical values will be correctly presented in an appropriate format, i.e. standard form or engineering notation. Learners will work to a specified numerical precision (as determined by the assessor) through the use of appropriate significant figures or decimal places.

For P7 and P8, learners will present the solution of a given complex engineering problem. The solution may not be complete, and there may be some inaccuracies or omissions, but there should be evidence of some proficiency in the use of differential and integral calculus. For example, learners solving a dynamics problem based on the acceleration and energy transfers involved with a moving vehicle would be expected to determine the maximum accelerating force and work done getting the vehicle up to given velocity.

Overall, the report should be logically structured and contain commentary on each stage of the solution. Rules of differentiation and integration should be applied correctly. It may contain some minor arithmetic errors, for example the value of a definite integral may be incorrect though the indefinite integral has been correctly deduced and the method chosen may not be optimal, for example expanding a function such as to integrate rather than using a substitution method. Minor 'carry through' errors are acceptable and there will be an appreciation of correct use of units, but there may be errors in their application.
For M1, learners will apply the correct skills and methods when producing the derivatives of functions and evaluating their gradients. Learners will correctly manipulate six routine and six non-routine functions (four polynomial, four trigonometric, two logarithmic and two exponential). Learners will compare the results, obtained graphically and analytically, for the two gradients being investigated, for example, there will be discussion about the numerical accuracy of the two methods.

Overall, learners’ numerical work will be accurate, using an appropriate degree of precision as specified by the assessor in significant figures or decimal places, and relevant units will be used for all functions. Limited number of arithmetic follow-through errors are acceptable for non-routine functions.

For M2, learners will apply the correct skills and methods when producing the integrals of functions and determining the properties of periodic functions. Learners will correctly manipulate eight routine and three non-routine definitive functions. At least eleven functions in total, including a polynomial, a trigonometric and an exponential non-routine function.

Numerical integration will be accurately completed for four definitive routine functions.

Overall, learners’ numerical work will be accurate, using an appropriate degree of precision as specified by the assessor in significant figures or decimal places, and relevant units will be used for all functions. Limited number of arithmetic follow-through errors are acceptable for non-routine functions.

For M3 and M4, learners will produce a reasoned analysis of a complex engineering problem, breaking it down into planned stages to obtain a solution. The method will apply differential and integral calculus appropriately at each stage, and the resulting solution will be of an acceptable degree of accuracy (as determined by the assessor).

Overall, the evidence will be logically structured, technically accurate and easy to understand. The planned method may contain some simplification and approximations to allow a solution to be calculated. Rules of differentiation and integration should be selected and applied correctly, for example using a substitution method to integrate terms rather than by expansion.

For D1, learners will demonstrate mastery in the application of differential calculus methods to the solution of given problems using mathematical functions. Learners will correctly and efficiently manipulate six routine and six non-routine functions.

A reasoned and balanced evaluation (argument) will be presented when considering how variables can be optimised for at least two non-routine functions related to an engineering context, for example determining the dimensions of a container of given volume so that its surface area is minimised, thereby minimising the material cost and environmental impact of the container.

Overall, the evidence will be logically structured and easy to understand by a third party with a mathematical background, who may or may not be an engineer. For example, learners will use mathematical terminology correctly and use relevant units when working with functions set in engineering contexts. Small and large numerical values will be correctly presented in an appropriate format, i.e. standard form or engineering notation. Learners will work to a specified numerical precision (as determined by the assessor), through the use of appropriate significant figures or decimal places.
For D2, learners will demonstrate mastery in the application of integral calculus methods to the solution of given problems using mathematical functions. Learners will correctly and efficiently manipulate eight routine and three non-routine functions.

Learners must present reasoned arguments when evaluating the use of analytical and numerical integration methods on at least two non-routine functions, for example finding work done by expressing parameters as a definite integral and then repeating the operation using Simpson's rule.

Overall, the evidence will be logically structured, easy to understand by a third party with a mathematical background, who may or may not be an engineer, and there will be correct use of mathematical terminology. Small and large numerical values will be correctly presented in an appropriate format, i.e. standard form or engineering notation. Learners will work to a specified numerical precision (as determined by the assessor) through the use of appropriate significant figures or decimal places.

In order to achieve D3, learners will demonstrate mastery in the application of calculus methods to the solution of a complex engineering problem. The identified problem must be sufficiently complex to allow learners to apply thinking methods, mathematical modelling and both differential and integral calculus methods to the solution of the problem. Learners must show that they are able to break a complex problem down into a series of manageable steps through the application of reductionism and logical thinking.

Learners will produce a full specification for the problem, based on gathered and given information and use this to produce a proposal; there must be evidence that this has been done before they embark on the mathematical manipulations. Evidence for this could be supported by an assessor observation record.

Overall, the evidence will be straightforward to understand by a third party with a mathematical background, who may or may not be an engineer, and there will be correct use of mathematical terminology and the application of relevant units. Small and large numerical values will be correctly presented in an appropriate format, i.e. engineering notation. Learners will work to specified numerical precision (as determined by the assessor) through the use of appropriate significant figures or decimal places.

Mathematical methods will be applied efficiently to the solution of the problem, for example using a logical approach to the solution and/or efficient use of a spreadsheet for a numerical analysis.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
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<tr>
<th>Criteria covered</th>
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<tr>
<td>P1, P2, P3, M1, D1</td>
<td>Differential Calculus to Solve Engineering Problems</td>
<td>An activity requiring learners to apply differential calculus methods to solve an engineering problem.</td>
<td>A report containing the results of learners’ analysis and calculation; carried out under controlled conditions.</td>
</tr>
<tr>
<td>P4, P5, P6 M2, D2</td>
<td>Integral Calculus to Solve Engineering Problems</td>
<td>An activity requiring learners to apply integral calculus methods to solve an engineering problem.</td>
<td>A report containing the results of learners’ analysis and calculation; carried out under controlled conditions.</td>
</tr>
<tr>
<td>P7, P8, M3, M4, D3</td>
<td>Applying Calculus to Solve a Specialist Engineering Problem</td>
<td>An activity requiring learners to apply calculus methods to solve a specialist engineering problem.</td>
<td>A report containing the results of learners’ analysis, planning and calculation; carried out under controlled conditions.</td>
</tr>
</tbody>
</table>

Essential resources

Learners will need access to maths support websites, spreadsheet software, e.g. www.mathcentre.ac.uk/students/topics

Indicative reading for learners

Textbooks


Unit 7: Further Engineering Mathematics

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Mathematics can be used to evaluate the intended and actual performance of a product or system at every stage of its life cycle. For example, mathematics may be used during the design of a product to determine whether it performs to specification. Statistics may be used during manufacturing processes as part of the quality control (QC) system and to determine the in-service reliability of a product. Statistics can also be used to evaluate the vast amounts of data that can be gathered about products and customers using mobile communications and the Internet of Things (IoT).

In this unit, learners will use algebraic techniques to solve engineering problems involving sequences, series, complex numbers and matrices. You will investigate the use of statistics as a data-processing and analysis tool, for example applying techniques used by a quality assurance engineer to monitor the output from a manufacturing process.

As a future engineer, you will need to understand and develop skills to solve problems using algebraic and statistical procedures. These are transferable skills and you will use them to support your study of other units in this course. This unit will help to prepare you for an apprenticeship or for employment in a range of engineering disciplines as a technician. You could also progress to a higher-level course, such as a Higher National Diploma (HND) or a degree in an engineering discipline.

Learning outcomes

On completion of this unit a learner should:
1. Examine how sequences and series can be used to solve engineering problems
2. Examine how matrices and determinants can be used to solve engineering problems
3. Examine how complex numbers can be used to solve engineering problems
4. Investigate how statistical and probability techniques can be used to solve engineering problems.
Unit content

1 Examine how sequences and series can be used to solve engineering problems

Arithmetic and geometric progressions

- Definitions:
  - sequence as an ordered collection of numbers $a, b, c, d$
  - progression as a sequence that increases in a particular pattern, i.e. there is a constant relationship between a number and its successor
  - series as the sum of the values in a sequence $a + b + c + d \ldots$
  - terminology – first term $a$, last term $l$, connection by law.

- Routine operations involve:
  - arithmetic progression (AP):
    - common difference $d$
    - general expression for a sequence in AP: $a, (a + d), (a + 2d), (a + 3d), \ldots, (a + nd)$
    - $n$th term (last term) $l = a + (n-1)d$
    - sum of an AP to $n$th term (arithmetic series):
      \[
      s = a + (a + d) + (a + 2d) + \ldots + (l-d) + l = \frac{1}{2} n(a + l)
      \]
  - geometric progression (GP):
    - common ratio $r$
    - general expression for a sequence in GP $a$, $ar$, $ar^2$, $ar^3$, $\ldots$, $ar^n$
    - sum of a GP to $n$th term (geometric series):
      \[
      s = a + ar + ar^2 + ar^3 + \ldots + ar^n = \frac{a(1-r^n)}{(1-r)}
      \]
    - convergence
    - sum to infinity.

- Non-routine operations involve:
  - engineering applications, e.g. lathe spindle speeds, cost of deep drilling, depreciation costs of capital equipment, gear box ratios, manufacturing estimation.
Binomial expansion

- **Definitions:**
  - Binomial expression that takes the form \((a + b)^n\)
  - Binomial theorem: when \(n\) is a positive integer
    \[(a+b)^n = a^n + na^{n-1}b + \frac{n(n-1)}{2!}a^{n-2}b^2 + \frac{n(n-1)(n-2)}{3!}a^{n-3}b^3 + \ldots + b^n\] (a finite series)
    which can be written as \((a+b)^n = \sum_{k=0}^{n} C_k a^{n-k}b^k\) where \(C_k = \frac{n!}{(n-k)!k!}\)
    alternative form \((1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \ldots + x^n\)
  - Binomial theorem when \(n\) is not a positive integer:
    \[(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \ldots + x^n\] for \(-1 < x < 1\) only (an infinite series)

- **Routine operations involve:**
  - Construction of Pascal’s triangle
  - Expansion of \((a + b)^n\) for positive values of \(n\) using Pascal’s triangle.

- **Non-routine operations involve:**
  - Expansion of \((1 + x)^n\) for non-positive integer values of \(n\) using the binomial theorem
  - Calculation of the \(n\)th term using the binomial theorem
  - Engineering applications, e.g. small errors, small changes, percentage changes, approximation of errors.

Power series

- **Definitions:**
  - A power series as \(f(x) = a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots + a_nx^n\)
  - A Taylor series as \(f(x) = f(a) + f'(a)(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \ldots + \frac{f^{(n)}(a)}{n!}(x-a)^n\)

- **Routine operations involve:**
  - A Maclaurin series as a Taylor series with \(a = 0\)
  - Convergence and divergence
  - Conditions for convergence and divergence.

- **Non-routine operations involve:**
  - Numerical value for \(e\) using a power series
  - Proof that \(\frac{dy}{dx}(e^x) = e^x\) using series
  - Engineering applications, e.g. error in area or volume for small error in measurement of length, oscillator frequency for an electrical circuit if components have small errors in their values.
2 Examine how matrices and determinants can be used to solve engineering problems

Matrices
- Definitions:
  - matrix type – element and order (row × column)
  - matrix terminology – element, row, column, order (row × column), equality, zero (null matrix), identity (unit) matrix, transpose, square, leading diagonal, triangular.
- Routine operations involve:
  - addition, subtraction, multiplication by a real number
  - inverse of a (2 × 2) matrix
  - solution of sets of simultaneous equations with two variables using inverse matrix methods.
- Non-routine operations involve:
  - multiplication of matrices
  - solution of sets of simultaneous equations with two variables using Gaussian elimination.

Determinants
- Definitions:
  - the determinant of a matrix as a useful value that can be computed from the elements of a square matrix, denoted by \( det(A) \) or \( |A| \)
  - a singular matrix is one with the determinant \( |A| = 0 \)
- Routine operations involve:
  - the determinant of a (2 × 2) matrix \( A = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \) using \( |A| = ad - bc \)
  - the inverse of a two-dimensional matrix \( A = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \) using \( A^{-1} = \frac{1}{|A|} \begin{pmatrix} d & -b \\ -c & a \end{pmatrix} \)
- Non-routine operations involve:
  - the determinant of a (3 × 3) matrix \( A = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix} \) using
    \[
    |A| = a \begin{pmatrix} e & f \\ h & i \end{pmatrix} - b \begin{pmatrix} d & f \\ g & i \end{pmatrix} + c \begin{pmatrix} d & e \\ g & h \end{pmatrix}
    \]
  - use of Cramer’s rule to solve for sets of simultaneous equations with two variables
  - engineering applications, e.g. simultaneous linear equations with more than two variables (electrical circuits, vector arrays, machine cutter paths).
3 Examine how complex numbers can be used to solve engineering problems

**Complex numbers**

- **Definitions:**
  - algebraic form (Cartesian, rectangular notation): \((a + jb)\)
  - real part, imaginary part, \(j\) notation, \(j\)-operator, powers of \(j\)
  - modulus: \(|a + jb| = \sqrt{a^2 + b^2}\)
  - argument: \(\arg(a + jb) = \tan^{-1}\left(\frac{b}{a}\right)\)
  - polar form \(r \angle \theta\); \(\theta\) is usually expressed in radians but may be in another angular measure
  - complex conjugate of \(y = a \pm jb\) as \(y^* = a \mp jb\)

- **Routine operations involve:**
  - placement of complex numbers on an Argand diagram
  - addition and subtraction in rectangular form
  - multiplication by a constant coefficient
  - conversion between rectangular and polar forms \((r \rightarrow p\) and \(p \rightarrow r\) ) using trigonometry and a scientific calculator
  - multiplication and division of complex numbers in polar form.

- **Non-routine operations involve:**
  - multiplication in rectangular form
  - division in rectangular form using the complex conjugate
  - de Moivre’s theorem: \((r \angle \theta)^n = r^n \angle n\theta\)
  - engineering applications, e.g. vectors, electrical circuit phasor diagrams, algebraic form (Cartesian, rectangular notation): \((a + jb)\)
  - real part, imaginary part, \(j\) notation, \(j\)-operator, powers of \(j\)
  - modulus: \(|a + jb| = \sqrt{a^2 + b^2}\)
  - argument: \(\arg(a + jb) = \tan^{-1}\left(\frac{b}{a}\right)\)
  - polar form \(r \angle \theta\); is usually expressed in radians but may be in another angular measure
  - complex conjugate of \(y = a \pm jb\) as \(y^* = a \mp jb\)
4 Investigate how statistical and probability techniques can be used to solve engineering problems

Statistical techniques

- Routine operations involve:
  - discrete data, continuous data, ungrouped data, grouped data, rogue values
  - presentation of data: bar charts, pie charts, histograms, cumulative frequency curves
  - measures of central tendency (location): arithmetic mean, median, mode
  - measures of dispersion: variance, standard deviation, range and inter-percentile ranges
  - linear relationship between independent and dependent variables, scatter diagrams, approximate equation of line of regression $y = mx + c$ represented graphically.

- Non-routine operations involve:
  - equation of linear regression line $y = mx + c$ where
    $$m = \frac{\sum_{i=1}^{N}(x_i y_i) - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N \sum_{i=1}^{N} x_i^2 - \left( \sum_{i=1}^{N} x_i \right)^2} \quad \text{and} \quad c = \bar{y} - m \bar{x}$$
    $$\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N} \quad \text{and} \quad \bar{y} = \frac{\sum_{i=1}^{N} y_i}{N}$$
  - correlation coefficient using Pearson's correlation
    $$r_{x,y} = \frac{N \sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{\sqrt{N \sum_{i=1}^{N} x_i^2 - \left( \sum_{i=1}^{N} x_i \right)^2} \sqrt{N \sum_{i=1}^{N} y_i^2 - \left( \sum_{i=1}^{N} y_i \right)^2}}$$

- Use of spreadsheets and/or scientific calculators to calculate the equation of the line of regression and correlation coefficient, e.g. tabulating calculations, using trendline and CORREL() functions in a spreadsheet, or a standard scientific calculator.

- Use of spreadsheets and/or scientific calculators to identify the most appropriate type of regression line, e.g. linear, logarithmic, exponential or variable power.

Probability distributions

- Routine operations involve:
  - normal distribution – shape and symmetry, skew, tables of the cumulative distribution function, mean, variance
  - normal distribution curve – areas under it relating to integer values of standard deviation.

- Non-routine operations involve:
  - confidence intervals for normal distribution and probability calculations.
Statistical investigation

- The use of appropriate mathematical methods to solve the given engineering problem.

- Engineering applications, e.g. inspection and quality assurance, calculation of central tendencies and dispersion, forecasting, reliability estimates for components and systems, customer behaviour, condition monitoring and product performance.

- Reflection on the problem-solving process and the solution obtained, making refinements if necessary.

- Presentation of the solution to the given engineering problem.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong> solve given problems using routine arithmetic and geometric progression operations</td>
<td><strong>M1</strong> solve given problems accurately, using routine and non-routine arithmetic and geometric progression operations</td>
<td><strong>D1</strong> evaluate, using technically correct language and a logical structure, engineering problems using non-routine sequence and series operations, while solving accurately all the given problems using routine and non-routine operations.</td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong> solve given problems using routine power series operations</td>
<td><strong>M2</strong> solve given problems accurately, using routine and non-routine power series operations</td>
<td><strong>D2</strong> evaluate, using technically correct language and a logical structure, engineering problems using non-routine matrices, determinant and complex operations, while solving accurately all the given problems using routine and non-routine operations.</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> solve given problems using routine matrices and determinant operations</td>
<td><strong>M3</strong> solve given problems accurately, using routine and non-routine matrices and determinant operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> solve given problems using routine complex number operations</td>
<td><strong>M4</strong> solve given problems accurately, using routine and non-routine complex number operations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Assessment and grading criteria

<table>
<thead>
<tr>
<th>P5</th>
<th>M5</th>
<th>D3</th>
</tr>
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<td><strong>To achieve a pass grade</strong> the evidence must show that the learner is able to:</td>
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<td><strong>To achieve a distinction grade</strong> the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</td>
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<td><strong>P5</strong> solve an engineering problem using routine central tendency, dispersion and probability distribution operations.</td>
<td><strong>M5</strong> solve an engineering problem accurately, using routine and non-routine central tendency, dispersion and probability distribution operations, providing an explanation of the process.</td>
<td><strong>D3</strong> evaluate the correct synthesis and application of statistics and probability to solve engineering problems involving accurate routine and non-routine operations.</td>
</tr>
<tr>
<td><strong>P6</strong> solve an engineering problem using routine linear regression operations.</td>
<td><strong>M6</strong> solve engineering problems accurately, using routine and non-routine regression operations, providing an explanation of the process.</td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

For P1 and P2, learners must demonstrate the correct use of routine operations (skills and methods) when working with given problems based on sequences and series.

Overall, minor arithmetic and scaling errors are acceptable, as are 'carry through' errors, provided that the basic method is sound. For example, a term in a sequence may be incorrectly calculated but the value used correctly in subsequent calculation of the series, affecting the final value. Learners will demonstrate an appreciation of the need for the correct use of units but there may be errors in their application. There will also be evidence of simple checks to determine if numerical answers are 'reasonable'.

For P3 and P4, learners must demonstrate the correct use of routine operations (skills and methods) when working on given problems based on matrices, determinants and complex numbers.

Overall, minor arithmetic errors are acceptable, as are 'carry through' errors, provided that the basic method is sound. Learners will demonstrate an appreciation of the need for the correct use of units but there may be errors in their application. Learners will include evidence of simple checks to determine if numerical answers are 'reasonable'.

For P5 and P6, learners will present the solutions of engineering problems involving measures of central tendency, dispersion and probability distribution. Ideally, they will research their own problems but if this is not possible then they can be given to learners. The solutions may not be complete and there may be some inaccuracies or omissions but there should be evidence of some proficiency of method. Learners will apply the appropriate routine operations (skills and methods) needed to process statistical data. For example, when evaluating sampled dimensional data from a machining operation, learners will present data appropriately and determine routine values such as the mean and standard deviation for a sample but may not compare the values with historical data. They will tabulate measurements and present data in a scatter graph and they may estimate the line of regression graphically.

Overall, the report should be logically structured. It may contain some arithmetic errors that 'carry through', for example the value of the mean of a set of sampled dimensional data from a machining operation may be incorrect, but that value used correctly to find the standard deviation. The methods chosen may not be optimal but the chosen statistical methods should be applied correctly. Minor errors and omissions are acceptable. For example, the axis titles on a scatter graph may be missing units. There will be an appreciation of correct use of units but there may be errors or inconsistency in their application. Learners will include evidence of simple checks to determine if numerical answers are 'reasonable'.

For M1 and M2, learners will accurately apply appropriate routine and non-routine operations (skills and methods) needed to solve given problems based on sequences and series.

Overall, the numerical work will be to an appropriate degree of accuracy, as specified by the assessor. For example, appropriate significant figures and decimal places. Solutions must be structured logically and the correct mathematical terminology and relevant units will be used, with limited number of minor errors or omissions in non-routine operations.
For M3 and M4, learners will accurately apply appropriate routine and non-routine operations (skills and methods) needed to solve given problems based on matrices, determinants and complex numbers.

Overall, the numerical work will be to an appropriate degree of accuracy, as specified by the assessor. For example, appropriate significant figures and decimal places. Solutions must be structured logically and the correct mathematical terminology and relevant units will be used, with limited number of minor errors or omissions in non-routine operations.

For M5 and M6, learners will present accurate solutions for engineering problems related to measures of central tendency, dispersion and probability distribution, breaking them down into planned stages to obtain solutions. They will apply appropriate routine and non-routine operations (skills and methods) needed to process statistical data accurately. For example, tabulation of data, graphical presentation, accurate calculations of mean and standard deviation comparing measured values with historical data, accurately produced annotated scatter graph (with chart title, axis titles including units and gridlines) and calculation of line of regression and correlation coefficient for a linear relationship and regression line for a non-linear relationship.

Overall, the numerical work will be to an appropriate degree of accuracy, as specified by the assessor or appropriate for the chosen problems being solved. Solutions will contain an explanation of the process that will be logically structured, and the correct mathematical terminology and relevant units will be used. There may be limited number of minor errors or omissions in non-routine operations. For example, when evaluating sampled dimensional data from a machining operation, learners may determine the mean and standard deviation for a sample and find a degree of correlation between samples, but not draw conclusions from, the values.

To achieve D1, learners will demonstrate mastery in the application of algebraic techniques to the correct solution of given problems involving sequences and series. Where appropriate to the non-routine problems, learners will correctly and efficiently manipulate formulae and present reasoned and balanced evaluations.

Overall, the evidence will be easily understood by a third party with a mathematical background, who may or may not be an engineer. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions that model engineering situations. Small and large numerical values will be correctly presented in an appropriate format, for example engineering notation or standard form. Learners must demonstrate that they are able to work to specified numerical precision, as specified by the assessor, through the use of appropriate significant figures.

For D2, learners will demonstrate mastery in the application of algebraic techniques to the correct solution of given problems involving matrices, determinants and complex numbers. Where appropriate with the non-routine problems, learners will correctly and efficiently manipulate formulae and present reasoned and balanced evaluations.

Overall, the evidence will be easily understood by a third party with a mathematical background, who may or may not be an engineer. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions that model engineering situations. Small and large numerical values will be correctly presented in an appropriate format, for example engineering notation or standard form. Learners must demonstrate they are able to work to specified numerical accuracy through the use of appropriate significant figures, as specified by the assessor.
In order to achieve D3, learners will demonstrate mastery in the application of the processing and evaluation of statistical data generated from engineering sources. The identified problems must be sufficiently complex to allow learners to apply both routine and non-routine operations (skills and methods) to their solution. For example, in terms of measures of central tendency and dispersion learners may evaluate one set of measured and four sets of equivalent historical data such as dimensional data from a machining operation or reliability data sourced from products in service. Before starting to process any data, learners will establish that the data sets are large enough to enable reliable analysis to be carried out. For regression, they will propose a theoretical relationship between two variables, collect data, calculate a mathematical relationship between dependent and independent variables using appropriate analytical and graphical methods, and reflect on the accuracy of the initial proposal for a linear and a non-linear relationship.

Overall, the evidence will be easily understood by a third party with a mathematical background, who may or may not be an engineer. There will be correct use of mathematical terminology and the application of relevant units. Learners will work to specified numerical precision, as determined by the assessor or that are appropriate for their chosen problems being solved, through the use of appropriate significant figures or decimal places. Small and large numerical values will be correctly presented in an appropriate format, i.e. engineering notation or standard form.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<th>Assessment method</th>
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<tbody>
<tr>
<td>P1, P2, M1, M2, D1</td>
<td>Sequences and Series to Solve Engineering Problems</td>
<td>An activity requiring learners to solve problems based on sequences and series.</td>
<td>An informal report containing the results of learners’ analysis and calculation; carried out under controlled conditions.</td>
</tr>
<tr>
<td>P3, P4, M3, M4, D2</td>
<td>Matrices, Determinants and Complex Numbers to Solve Engineering Problems</td>
<td>An activity requiring learners to solve problems based on matrices, determinants and complex numbers.</td>
<td>An informal report containing the results of learners’ analysis and calculation; carried out under controlled conditions.</td>
</tr>
<tr>
<td>P5, P6, M5, M6, D3</td>
<td>Statistical and Probability Techniques to Solve Engineering Problems</td>
<td>An activity requiring learners to solve engineering problems based on statistical data.</td>
<td>An informal report containing the results of learners’ analysis and calculation of measured and supplied data; carried out under controlled conditions. Where appropriate, processing of statistical data can be done by spreadsheet.</td>
</tr>
</tbody>
</table>
Essential resources

For this unit, learners must have access to:

- maths support websites, e.g. www.mathcentre.ac.uk/students/topics
- spreadsheet software and/or a scientific calculator such as Casio FX-85GT.

Indicative reading for learners

Textbooks


Unit 8: Mechanical Measurement and Inspection Technology

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Many of the products we use daily rely on components being manufactured accurately. The selection of a process to manufacture a product or component is sometimes chosen because of its speed or ability to shape materials, and they are always chosen because of the level of accuracy. Unfortunately, there will always be variation in these processes, and engineers must control the variation to avoid faulty products and/or components being manufactured.

In this unit, learners will cover the principles and technology applied to a range of mechanical measurement equipment and inspection methods. They will develop the skills required to use a range of equipment, including comparators and gauges. Learners will develop and use statistical process control (SPC) charts to inspect components and determine if the process is in control. They will also undertake a process-capability study on a precision-manufacturing process to increase productivity and establish whether the process is capable.

As an engineer, learners may need to understand and acquire the practical skills needed to control the manufacture of high-precision components. This unit prepares them for a mechanical or manufacturing engineering apprenticeship or for progression to higher education, and for technician-level roles in industry, such as a quality inspector or a junior production engineer involved in shop-floor machine management.

Learning outcomes

On completion of this unit a learner should:

1. Explore the principles applied to mechanical measurement and inspection methods as used in industry
2. Carry out mechanical measurement and inspection methods to determine if components are fit for purpose
3. Explore statistical process control to inspect components and increase productivity
4. Carry out a process capability study to establish machine suitability for a given application.
Unit content

1 Explore the principles applied to mechanical measurement and inspection methods as used in industry

Limits and fits
Principles applied to the use of limits and fits:
- concepts of limits and fits
- definitions of the types of fits – clearance, transition, interference

Tolerances
Principles applied to the use of tolerances:
- standard symbols and interpretation, maximum material condition, least materials condition, maximum variation of form
- grades of tolerance applicable to hole tolerances and shaft tolerances
- reference to British Standards, e.g. BS 969, BS 1134, BS 2634, BS 4500 or other relevant international equivalents
- type of high-precision manufacturing processes, e.g. turning, milling, grinding, honing.

Gauge types
Designing gauges for inspection activities as used in industry:
- limit gauge types, including plug, ring, gap and taper; gauge materials, including high carbon, alloy steel and cemented carbide
- Taylor’s principle, principle of go/no-go gauging (limit gauges)
- slip gauges as references for length standards, classification of slip gauges, multiple slip gauge use (wringing), care and maintenance required
- component features including: hole diameter, shaft diameter, other external dimension/size, tapered hole.

2 Carry out mechanical measurement and inspection methods to determine if components are fit for purpose

Measuring practice
Principles applied to measuring practice:
- precision – how close measurements are to one another
- accuracy – how close measurements are to the ‘true answer’
- uncertainty – the quantification of doubt about the measurement result, tells us something about its quality
- resolution – the smallest difference in dimensions that the measuring equipment can detect or distinguish.
Types of mechanical measurement

- Linear measuring equipment:
  - equipment used for linear accuracy, e.g. verniers, callipers (digital), micrometers, including external, internal and depth
  - principles, including scales, sources of error, specific calibration issues.

- Surface-texture measuring equipment:
  - equipment used for surface texture measurement, e.g. Rubert gauges, stylus measuring equipment
  - principles, including surface texture symbols, roughness average, waviness, finish, amplitude parameters, spacing parameters.

- Straightness, squareness and flatness measuring equipment:
  - equipment used for determining straightness, squareness and flatness, e.g. straight edges, engineer's square, autocollimator, carriage and reflector, optical square
  - principles, including wedge method, level method, line or surface datum, optical reflection, focal point.

- Angular measurement equipment:
  - equipment used for determining angular accuracy, e.g. sine bar, angle gauges, angle dekkor, vernier bevel protractor, clinometer
  - principles, including trigonometry functions, optical reflection, focal point.

Comparators

- The application of comparators to inspect manufactured features.

- Types of comparators, including:
  - mechanical type, e.g. dial test indicator (DTI), Sigma, Johansson Mikrokator, Venwick
  - electrical type, e.g. digital, Wheatstone bridge circuit
  - optical type, e.g. Eden-Rolt millionth comparator
  - pneumatic type, e.g. Solex gauge.

- Principles, e.g. magnification, cosine errors, specific calibration issues.

Gauging system

Gauges to inspect manufactured features:

- gauge types, including plug, ring, gap and taper
- principles involving the use of slip gauge as references for length standards, use with ancillary equipment, including DTIs, care and maintenance required, wringing.
Component features, types and manufacturing processes

- Component features, including round (external or internal), linear (length, depth), texture, straightness, 900 angles and flatness.
- Types of component, including the jaw of a toolmaker’s clamp, precision dowels, machine bed, vee block, vehicle engine block, piston.
- Typical manufacturing high-precision processes, e.g. grinding, milling, honing or high-volume turning.

3 Explore statistical process control (SPC) to inspect components and increase productivity

Principles of statistics

Statistics used in inspection methods to increase productivity.

- Principles of statistics, including:
  - types of data concerned with precision manufacturing, e.g. variable or continuous, attribute or discrete
  - characteristics, including population, sample, sample size, frequency, mean, mode, median, range, variance, standard deviation
  - non-normal distribution curves, e.g. skewed, bimodal, flat topped
  - characteristics of a normal distribution including interpreting the change in shape, spread and position of the distribution over time.
- Graphical analysis, e.g. bar charts, histograms, stem and leaf diagrams, Pareto diagrams, box plots, run charts, time series charts.
- Variation in manufacturing processes, e.g. between components, within components, machine to machine, batch to batch, time to time.
- Causes of variation, e.g. tool breakage and wear, voltage fluctuations and machine wear.

SPC procedure

SPC in inspection:

- developing SPC procedures involving pre-process control procedures, including product/process selection, identify critical characteristics, determine type of data, define the measurement system, design check sheet/chart, data-collection plan, test procedure
- design of control procedure; calculating sample size, frequency and upper and lower control limits, e.g. variable control charts such as X and R charts, attribute charts such as np, p, c and u
- use of control procedure, and mean and range charts, including plotting data, monitoring charts, interpreting charts and identifying of out-of-control conditions
- outcomes from use, e.g. modify process conditions when necessary, audit process.
4 Carry out a process capability study to establish machine suitability for a given application

**Pre-process capability study procedure**

Procedures involved in designing a process-capability study:

- suitable process, e.g. grinding, milling, honing, turning
- developing specification limits and control chart limits
- use and consequence of relative precision index, e.g. high, medium, low
- equations, e.g. $C_p$, $C_{pk}$, sigma score ($Z$)
- modified control chart limits.

**Process capability study**

Process-capability study to establish machine suitability:

- graphical process-capability sheet
- determine process-capability and parts per million outside upper and lower specification limits
- analysis of information
- defining improvement activities to improve the process capability
- presenting findings in a process-capability report.
## Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
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</tr>
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<tbody>
<tr>
<td><strong>P1</strong></td>
<td>apply the principles of limits and fits and tolerances to design a range of limit gauges</td>
<td><strong>M1</strong> analyse, including the use of slip gauges, how different limit gauges rely on the principles of limits and fits and tolerances</td>
<td><strong>D1</strong> evaluate, using language that is technically correct and of a high standard, the design of limit gauges that are fit for purpose and rely on the principles of limits and fits, tolerances and the use of slip gauges as a reference to the standard</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>measure, using three different types of mechanical measurement equipment, a range of component features</td>
<td><strong>M2</strong> measure accurately and precisely, using three different types of mechanical measurement equipment, a range of component features</td>
<td><strong>D2</strong> evaluate the resolution and measurement of uncertainty for comparators and/or gauges against the mechanical measurement equipment used to inspect a range of components</td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>select two different types of comparator and gauges and inspect a range of component features</td>
<td><strong>M3</strong> compare the capabilities and use of two different types of comparator against different types of gauges used to inspect a range of component features</td>
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### Assessment and grading criteria

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<td><strong>P4</strong> explain how the principles of statistics and graphical analysis are applied to represent and display variation found during inspection</td>
<td><strong>M4</strong> analyse, an in-control process using a statistical process control procedure involving variable control and attribute charts in relation to effectiveness of variation control and the outcomes from their use</td>
<td><strong>D3</strong> evaluate how statistics have influenced the design and successful use of process control charts and a capability study to demonstrate where an improvement to the process can be achieved.</td>
</tr>
<tr>
<td><strong>P5</strong> design and use a statistical process control procedure involving variable control and attribute charts</td>
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<td></td>
</tr>
<tr>
<td><strong>P6</strong> design a process capability study</td>
<td><strong>M5</strong> analyse as part of a process capability study the accuracy of a process and produce a modified control chart, explaining its use.</td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> perform a process capability study to establish if a machine is capable of producing components to the required precision.</td>
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</table>
Essential guidance for tutors

Assessment

For P1, learners will give clear evidence that a set of limit gauges have been designed to inspect four different component features, although there may be some confusion between the use of tolerances. They may have applied their position across the gauge sizes incorrectly, leading to some inaccuracies in the design of the gauges. For example, the wrong gauge tolerance may have been used, and when using slip gauges the overall slip gauge size may be incorrect or more slip gauges were used than was necessary.

Overall the explanations should be logically structured, although basic in parts and they may contain minor technical inaccuracies relating to engineering terminology, such as using the term ‘block gauges’ instead of ‘slip gauges’. Also, the calculations may contain some minor arithmetic errors.

For P2, learners will record in a logbook their results from using three different types of mechanical measurement equipment, to measure at least three different features, for example: linear dimensions, surface texture, straightness, squaring, flatness or angular dimensions. Learners may not have selected the correct equipment but will have recorded the measurements taken.

For P3, learners will correctly select two different types of comparator and appropriate gauges. They will record the measurements and ‘no’ and ‘no go’ decisions on at least three different components covering, across these components, at least one round, linear, texture and geometric feature.

Overall, the evidence will be logically structured. It may contain some inaccuracies with the use of engineering terminology and there may be some minor inaccuracies in the results. For example, learners may only record one measurement of each feature, and some of the gauge and comparator sizes and inspection decisions may not be accurate.

For P4, P5 and P6, learners will explain clearly how the principles of statistics and graphical analysis can be used to show variation in process outcomes and give confidence to monitor the variation of a process. Also, the design and use of the control charts should contain appropriate limits and the process trends should be correct, and the charts should be appropriate for a machine operator to use.

The capability report will contain evidence of how the data and the capability equations have been used to develop specification and control chart limits for the capability study to be carried out on a suitable process.

Learners will plot the data to explain the process and its capability, and the trends in the plotted data will be correct.

Overall, the evidence should be logically structured, although basic in parts and it may contain minor technical inaccuracies relating to engineering terminology, such as confusion between control limits and component tolerances. Also, there may be some minor numerical errors, for example a control chart entry may have been incorrectly plotted. The evidence should be clear to a third party who is not an engineer.

For M1, learners will be consistent in their analysis applied across all the requirements covering the correct use of slip gauges, and the reliance on the principles of limits and fits and tolerances will be explained well. There will be a clear indication that the designed set of limit gauges are appropriate for the component specifications given, and easy to use to inspect four different component features.
Overall, the analysis should be logically structured, technically accurate and easy to understand.

For M2 and M3, learners will select the correct measuring equipment and all measurements taken will be precise and accurate.

The comparison will be consistent across all the requirements of the correct selection and use of comparators and gauges. For example, the principles involved for each comparator and gauge will be referred to, such as the correct use of the focal point when using an autocollimator and angle dekkor being similar. Also, reference will be made that surface texture measurement can be found by comparison to Rubert gauges or can be measured more accurately arriving at values for roughness and waviness. Learners will provide accurate and precise measurements and correct ‘no’ and ‘no go’ decisions throughout on at least three different engineering components.

Overall, the analysis should be logically structured, technically accurate and easy to understand.

For M4 and M5, learners will draw conclusions about the process being monitored and use statistics to demonstrate that the process is under control. Learners will cover the effectiveness of the control method.

Learners will produce a modified control chart that will be fit for purpose and the capability report will clearly explain the use of the modified control chart.

Overall, the analysis should be logically structured, technically accurate and easy to understand.

For D1, learners will produce evidence that is a balanced evaluation of the gauge and design principles used, with appropriate references to the standards applicable to the design and use of limit gauges. For example, it will make reference to the types of fit and maximum metal condition/least materials condition, and Taylor’s principle showing how these have influenced the gauge tolerances found in the relevant standards. The evidence will include a reasoned conclusion about the fitness for purpose of the designed gauges, and the use of slip gauges as a reference to the standard.

Overall, the evidence will be logically structured, use the correct technical engineering terms and will contain high-quality written language, for example it will be grammatically clear.

For D2, learners will produce evidence that includes a balanced evaluation of the resolution and measurement of uncertainty resulting from the measurement of components using comparators, gauges and mechanical measurement equipment. The evidence will contain a reasoned conclusion about the use of different types of inspection and measurement equipment. For example, it should include the correct use of scales during measurement and how sources of error are accommodated and why calibration is important.

Overall, the evidence on the practical activities should be logically structured, use the correct technical engineering terms and will contain high-quality written language, for example it will be grammatically clear.

For D3, learners will have information that clearly demonstrates how statistics have influenced the design of the control charts and their use in the statistical process control evaluation. For example, how mean and range are used as known variation control, and how the sample sizes set produce statistically sound outcomes. It
should be clearly shown how the application of these principles of statistics makes the control procedure effective through the:

- accurate and precise measurement of component features and that it is representative
- use of appropriate limits that do not unnecessarily restrict the process (‘over or under control’).

The capability report will also demonstrate how an improvement to the process can be achieved. This improvement will be realistic, for example a lower material machine feed rate or higher workpiece machining speed can lead to better accuracy.

Overall, the evidence will be logically structured, use the correct technical engineering terms and will contain high quality written language, for example it will be grammatically clear.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, M1, D1</td>
<td>Gauge Design and the Principles of tolerancing</td>
<td>An activity requiring learners to research gauge design and the principles of tolerancing.</td>
<td>A report focusing on gauge design and the principles of tolerancing, including notes about limits and fits. The report to be based on research and to include the design of gauges to inspect four different product features.</td>
</tr>
<tr>
<td>P2, P3, M2, M3, D2</td>
<td>Practical Measurement and Inspection Activities</td>
<td>Learners carry out practical measurement and inspection tasks.</td>
<td>A range of practical measurement and inspection activities recorded in a developmental logbook. Evidence will be a measurement and inspection report, annotated drawings/photographs of the components and observation records/witness statements.</td>
</tr>
<tr>
<td>P4, P5, P6, P7, M4, M5, D3</td>
<td>Statistical Process Control (SPC) and Process Capability Studies</td>
<td>An activity requiring learners to research statistics and their application to control procedures. Learners produce a capability report and assess its suitability.</td>
<td>A report covering the use of basic statistics and how these can be applied to control procedures during inspection. A capability report focusing on the outputs from a particular process, reporting on its suitability. Both reports should include notes and sketches and will be supported by a developmental logbook.</td>
</tr>
</tbody>
</table>
**Essential resources**

For this unit, learners must have access to:

- a range of gauges (limit, slip), linear measuring equipment, surface-texture measuring equipment, straightness, squareness and flatness measuring equipment, angular measuring equipment, a range of different types of comparators as required by the learning aims and unit content

- components to be measured (such as those listed under key content area 'Component features, types and manufacturing processes')

- a range of British or other relevant international standards, as required by the unit content

- a range of data from different precision processes to allow control charts and process capability to be established.
Unit 9: Aircraft Workshop Methods and Practice

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Familiarity with the aircraft workshop, components, tools and information sources and standards, together with developing a knowledge of mechanical and electrical inspection and fitting processes, provide an essential foundation for all prospective aircraft engineering technicians and engineers, irrespective of their chosen specialism.

In this unit, learners will be introduced to the aircraft workshop environment and be made aware of safety and operational processes, as well as the function and safe use of aircraft hardware and consumable components, and tools. They will develop practical skills by carrying out a series of mechanical and electrical workshop inspection and fitting activities. Finally, learners will be asked to reflect on how their general engineering skills, workshop inspection and fitting skills and behaviours were applied during the unit.

This unit will help to prepare learners for an aircraft engineering apprenticeship as well as, more specifically, assisting them in gaining employment in an aircraft technician role. Alternatively, they could choose to continue their studies in higher education.

Learning outcomes

On completion of this unit a learner should:

1. Explore safe working practices and suitable component selection in an aircraft workshop environment
2. Carry out processes to inspect and fit aircraft mechanical hardware safely that will help to ensure airworthiness
3. Carry out processes to inspect and fit aircraft electrical hardware safely that will help to ensure airworthiness
4. Review mechanical and electrical workshop inspection and fitting processes and reflect on personal performance.
Unit content

1 Explore safe working practices and suitable component selection in an aircraft workshop environment

Workshop safety procedures and housekeeping
Safety procedures, or other relevant international equivalents, and action to be followed, including:

- awareness of local workshop electrical safety hazards and actions, including:
  - electrical hazards when handling electrical power tools and circuit boards
  - electrostatic hazards with sensitive electrical instruments and tools
  - electric shock prevention methods
  - first-aid treatment and actions for electric shock
  - safety and pre-use checks when using portable and static electrical driven tools and machinery
- care and handling of low/high pressure gases, including compressed air lines, gas bottles, special precautions when handling oxygen and cryogenic substances
- control of hazardous substances, including handling and storage of hydraulic fluids, lubricants, fuels, paints, cleaning fluids and corrosive substances
- safety equipment to be used and procedures to followed when working at height
- compliance with workshop health and safety provision and procedures, including:
  - the care, application and use of firefighting equipment, positioning of fire points and fire drills
  - first-aid facilities and equipment, local procedures, accident/incident recording
- compliance with manual handling operations and personal protection regulations, including:
  - use of protective clothing
  - hand, eye and ear protection when handling sheet metal, cutting tools and corrosive substances, and using workshop machinery and tools
  - personal hygiene, and use of barrier creams.

Workshop information sources and standards
- Awareness of and compliance with civil and military information sources or other relevant international equivalents, e.g.:
  - civil publications of aviation transport association British Aviation Transport Association (BATA) 100 series, presented in written, microfilm and computer form, Civil Aviation Authority (CAA) publications, European Aviation Safety Agency (EASA) publications
  - military aviation aircraft publications AP101 series for maintenance and repair, military specifications (MIL SPEC), defence standards (DEF STAN)
  - other information sources, such as printed maintenance and repair manuals, microfilm and microfiche readers, computer databases, posters, wall charts, tables.
● Awareness of and compliance with standards or other relevant international equivalents, including:
  o fluids BS 2917, International Standards Organization ISO1219
  o electrical BS 3939, European Standard EN 60617-2-11
  o drawing BS 8888-2013
  o limits, fits, tolerances EN 20286.

**Tool management**

Tool control, care and use, including:

● tool control methods, including shadow boards, portable servicing kits, toolboxes, tool tags, electronic coded labelling, booking in/out systems

● missing tool and loss article actions

● user precautions, pre-use and safety checks for workshop tools, including:
  o marking out and work-holding tools, e.g. rule, callipers, scribe, centre punch, fitter’s square, combination set, surface plate, clamps, vices, griper pins
  o precision measuring instruments, e.g. micrometers, vernier callipers, vernier height and depth gauges, bevel protractors and their calibration and control
  o cutting and metal removal tools, e.g. guillotines, hacksaws, files, electrical and pneumatic drills, nibblers, reamers, grinding machines, countersinks
  o riveting tools, e.g. bend bars, bending machines, hand and powered riveting pliers, guns, lazy tongs, reaction blocks, countersinks
  o assembly/dismantling tools, e.g. steel and hide faced hammers, pliers, spanners, wrenches, torque wrenches, screwdrivers
  o electrical cable crimping and sheathing tools and equipment.

**Hardware and consumable components**

● Recognition, care and use of hardware components, including:
  o fluid plumbing, e.g. flexible hoses, rigid pipes, unions, fittings, connectors
  o transmissions, e.g. springs, belts, chains, pulleys, sprockets, gears, bearings, screwjacks, lever devices, push-pull rods
  o control cables, e.g. control cable runs, Bowden cable, teleflex, screwed and pinned end fittings, turnbuckles, turn barrels, cable tensioners
  o electrical, e.g. wire types, polyvinylchloride (PVC), nylon, Kapton®, Teflon™, Tezel, connectors, terminations, plugs, sockets, cleats, sheathing.

● Identification and use of consumable components, including:
  o threaded fasteners, including screws, bolts, studs, nuts, washers, friction-locking devices, lock wire, split pins
  o fasteners, including quick release, toggle
  o rivets, including solid universal/pan head, solid countersunk, blind and hi-shear rivets, e.g. Tucker POP®, Avdel®, Chobert®, Jo-Bolts.

● Consequences of non-compliance with information sources and standards, tool management and hardware and consumable components when carrying out mechanical and electrical inspection and fitting processes.
2 Carry out processes to inspect and fit aircraft mechanical hardware safely that will help to ensure airworthiness

Preparation for mechanical hardware inspection and fitting processes
- Consult information sources to determine aircraft mechanical hardware inspection and fitting processes, including standards.
- Identify and select all required consumables and hardware components for designated mechanical inspection and fitting activity, from information sources.
- Comply with laid-down processes, including tests and inspection checks, for designated mechanical fitting activity.

Mechanical hardware inspection and fitting processes
- Mechanical hardware component inspection and fitting processes, e.g.:
  - sheet metal structure and panels
  - scab patch or insert repairs
  - panel fasteners
  - fluid plumbing
  - transmissions
  - control cable runs.
- Quality control checks, including:
  - fitting activities in compliance with information source procedures, standards and limits
  - visual and physical inspection checks, e.g. wear, serviceability, correct fitting and assembly, security of attachment, locking, freedom, sense and range of movement, tolerances, limits and fits
  - mechanical inspection and fitting checks, including dimensional accuracy, tolerance, critical dimensions, joint quality, surface finish.

3 Carry out processes to inspect and fit aircraft electrical hardware safely that will help to ensure airworthiness

Preparation for electrical hardware inspection and fitting processes
- Consulting information sources to determine aircraft electrical hardware inspection and fitting processes, including standards.
- Identifying and selecting all required consumables and hardware components for designated electrical inspection and fitting processes, from information sources.
- Complying with laid-down processes, including tests and inspection checks, for designated electrical fitting processes.

Electrical hardware inspection and fitting processes
- Electrical hardware inspection and fitting processes, e.g.:
  - electrical cable crimping
  - electrical cable replacement
  - electrical terminations, plugs and sockets
  - sheathing, assembling and looming cable runs.
• Quality control checks, including:
  o fitting processes in compliance with information source procedures, standards and limits
  o electrical checks for continuity, bonding and insulation
  o visual and physical inspection checks, e.g. wear, damage, serviceability, correct fitting and/or assembly, security of attachment.

4 Review mechanical and electrical workshop inspection and fitting processes and reflect on personal performance

Lessons learned from workshop inspection and fitting processes

The scope of the lessons learned should cover:

• health and safety skills, to include familiarity and compliance with laid down health and safety procedures and hazard prevention actions when carrying out mechanical and electrical inspection and fitting processes

• aircraft workshop mechanical and electrical inspection and fitting skills, e.g. to include interpreting information sources, tool care, control and use, selection of hardware and consumables components, good husbandry of the work area, sustainability, e.g. efficient use of hardware, energy usage and waste products

• general engineering skills, e.g. mathematics and interpreting drawings.

Personal performance when carrying out workshop inspection and fitting processes

Understanding relevant behaviours for working in an aircraft workshop, including:

• taking initiative and responsibility for own actions when applying knowledge and practical skills to mechanical and electrical inspection and fitting processes. This is so that they are safe, efficient and independent, e.g. selecting and using appropriate tools and hardware components

• communication and literacy skills to interpret and comply with workshop health and safety processes, and to follow and implement instructions appropriately and to explain own intentions to others

• problem solving issues as they occur, e.g. when correct tensioning of a control cable after installation results in the turn barrel being out of safe alignment.
### Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<td><strong>P1</strong> explain how information sources and standards are effectively applied to ensure aircraft airworthiness</td>
<td><strong>M1</strong> assess the possible effects on aircraft airworthiness of inspecting and fitting mechanical and electrical components that comply and do not comply with safe working practice</td>
<td><strong>D1</strong> justify, using language that is technically correct and of a high standard, the possible effects on aircraft airworthiness of inspecting and fitting mechanical and electrical components that comply and do not comply with safe working practice and suggest actions to mitigate these effects</td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong> explain how effective tool management and the correct selection of hardware and consumable components ensure aircraft airworthiness</td>
<td><strong>M2</strong> inspect and fit accurately and efficiently two appropriate mechanical hardware components</td>
<td><strong>D2</strong> refine, during the process, the inspection and fitting of mechanical and electrical hardware components to ensure system serviceability and integrity while complying with safe working practice</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> inspect and fit two appropriate mechanical hardware components safely</td>
<td><strong>M3</strong> inspect and fit accurately and efficiently, two electrical hardware components</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> inspect and fit two appropriate electrical hardware components safely</td>
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<tr>
<td><strong>P5</strong> explain how health and safety, mechanical and electrical inspection and fitting processes, and general engineering skills were applied effectively in an aircraft workshop</td>
<td><strong>M4</strong> recommend improvements to the mechanical and electrical hardware component inspection and fitting activities and to the relevant behaviours applied.</td>
<td><strong>D3</strong> demonstrate consistently good technical understanding and analysis of the mechanical and electrical hardware component workshop inspection and fitting activities, including the application of relevant behaviours and engineering skills to a professional standard.</td>
</tr>
<tr>
<td><strong>P6</strong> explain how relevant behaviours were applied effectively to mechanical and electrical inspection and fitting processes.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will know workshop safety procedures and practices that apply to mechanical and electrical inspection and fitting activities. Specifically, they will explain how information sources and laid-down standards are applied to ensure safe working practice. Finally, for P2, they will demonstrate an understanding of workshop tool care and control (management) methods, as well as the identification methods and codes used for aircraft consumable parts and hardware components.

Overall, the explanations will be logically structured, although basic in parts. They may have one or two omissions in their selection of information sources and standards that are applied across all areas of workshop practice. They may also fail to correctly identify all hardware and consumable components from their packaging, although still being aware of their purpose.

For P3 and P4, learners will safely complete two mechanical and two electrical inspection and fitting activities. Evidence that the particular workshop activity has been completed safely and in accordance with laid-down procedures may be obtained from observation, witness statements and learners’ written accounts.

There may be minor errors in accuracy and in the approach taken towards the completion of the allotted workshop activity and on completion; the hardware component will be fit for purpose. For example, a control system turnbuckle may be fit for purpose, as the turnbuckle end fittings are safety fitted and the wire locking is seen to be laid in the correct direction. However, the cut ends of the wire may not have been turned over correctly, causing a possible injury hazard. Another example is fitting a sheet metal insert where it would be acceptable if there are one or two minor errors, such as with the non-critical dimensions being out of tolerance and minor surface finish marks, providing they do not degrade the integrity of the repair.

For P5 and P6, learners will show in their evidence (for example, a technical report of between circa 500 and 1000 words) the lessons learned during each of the two mechanical and two electrical inspection and fitting activities. The evidence will explain the:

- actions taken to ensure their own personal safety and the safety of others in the workplace, such as the use of personal protective clothing, pre-use checks and care and control procedures for tools and equipment, and how any unforeseen safety issues were dealt with
- mechanical and electrical inspection and fitting skills, such as using pneumatically and electrically powered riveting, crimping and cutting tools, and the skills needed to correctly dismantle, assemble and check hardware components
- general engineering skills, such as the interpretation of engineering drawings and other relevant information in maintenance and repair manuals, and the reading and interpretation of measurements taken using precision instruments
- relevant behaviours that were applied when working in an aircraft workshop, such as time management to ensure completion of work to deadlines, good husbandry to ensure cleanliness and safety in and around the work area.
Overall, the evidence will be well organised and laid out clearly, so that a third party would be able to understand how learners’ skills have been applied. Efforts will be made to use some technical language where appropriate, although there may be some inaccuracies with spelling and grammar. Some parts of the evidence may be considered in greater depth than others.

For M1, learners will consider in the assessment the consequences of both compliance with and the failure to comply with or the misinterpretation of laid-down safety and operational standards and procedures for aircraft workshop practices. For example, the consequences of mishandling pneumatically/electrically powered tools, the misinterpretation of labelling for hardware consumables or the failure to carry out all necessary quality control checks.

Overall, the assessment will be logically structured, technically accurate and easy to understand.

For M2 and M3, learners will accurately and efficiently inspect and fit three mechanical and two electrical hardware components. Evidence of the efficiency of the method being undertaken may be gauged by those witnessing or testifying to the logical approach adopted by learners. This will be in respect of information gathering, the handling and interpretation of documentation, order of fitting operations, and sequence and nature of stage inspection checks.

Accuracy will be measured against the laid-down standards given in the appropriate information sources, and evidenced from the results of checks and/or measurements carried out during each particular activity. For example, when fitting a sheet metal insert, the measurements for rivet pitch, land and allowance meet or are within the tolerances laid down on the drawing/s or those given in aircraft maintenance or repair manuals.

For M4, learners will make recommendations as to where improvements could be made. For example:

- the logic in the order of the steps and stage inspection checks made in the method, such as, ensuring security of attachment and correct assembly of the hardware component prior to carrying out functional test and checks
- the management of health and safety to decrease the risk of harm to self and others, for example posting warning notices before post-fit functional tests and/or inspection checks are carried out, where moving parts are to be involved
- applications of relevant behaviours to ensure time goals are met, and inspection and fitting practice is completed in a more efficient manner.

Overall, the improvements suggested will be reasonable and practical, and explanations will be professional and engineering terminology will be used accurately. Some parts of the evidence may have more emphasis than others making it more difficult for a third party to understand.

For D1, learners will justify the need for laid-down workshop procedures, standards, safety precautions and control measures. This justification must include an analysis of the consequences associated with the misinterpretation of operational procedures and sub-standard workmanship in the workshop itself, but also consideration of the wider implications for aircraft airworthiness resulting from both compliance with and lapses in workshop safe working practice. Learners will suggest actions to mitigate the effects of non-compliance, for example the amendment of a specific procedure where it is seen that the addition of essential stage checks is required or, the amendment of the text to ensure that ambiguity of meaning is removed.
For example, a reasoned argument as to why it is necessary to have written workshop procedures on the management (care and control) of tools and to have those to ensure the correct identification and fitting of hardware parts and components, might be reinforced by providing examples from research showing the subsequent detrimental effects on aircraft airworthiness, in the event of misinterpretation or non-compliance.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured and use correct technical engineering terms, and will be of a high standard of written language and be, for example, grammatically correct.

For D2, learners will continually ensure throughout their mechanical and electrical hardware inspection and fitting activities that the hardware component being removed and fitted is returned to full serviceability. Learners will also ensure that the surrounding structure or systems affected are, through appropriate stage checks and rectification, kept and remained in a fully airworthy condition. For example, when replacing a pulley wheel in an aircraft flying control cable run, the pulley wheel will be replaced accurately and correctly. Inspection checks will also be carried out on the disassembled cable run to ensure the integrity and serviceability of all other components, replacing those that are unserviceable, with the requisite checks being carried out on the whole system as well as on the pulley wheel, post replacement.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For D3, learners will provide evidence in their analysis of how improvements have been made throughout the activity to the serviceability and integrity of the component and/or system or structure, in order to meet with professional laid-down airworthiness and safety standards.

Learners will demonstrate consistently good technical understanding of all aspects of the allotted activity, including the application of relevant behaviours and engineering skills to a professional standard. For example, learners will take responsibility for their own actions and safety, before, during and after the inspection and fitting of an electrical cable loom to a pre-prepared circuit board, ensuring that all relevant electrical safety precautions and pre- and post-quality checks have been accurately completed for the cable loom and for the circuit into which it is fitted.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, D1</td>
<td>Safe Working Practices and Suitable Component Selection</td>
<td>An activity requiring learners to research safe working practices and suitable component selection.</td>
<td>A report focusing on the nature and use of information sources, including safety procedures and standards covering aircraft workshop mechanical and electrical working practices, together with the results from recognition exercises to select aircraft hardware and consumable components.</td>
</tr>
<tr>
<td>P3, P4, M2, M3, D2</td>
<td>Inspecting and Fitting Aircraft Mechanical and Electrical Hardware</td>
<td>Learners inspect and fit aircraft mechanical and electrical hardware.</td>
<td>A series of practical workshop tasks to safely undertake mechanical and electrical inspection and fitting processes. Evidence will include: finished components, observation records/witness statements, annotated photographs and drawings and completed record of quality control measures needed to complete the fitting processes.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
<td>Scenario</td>
<td>Assessment method</td>
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</tr>
<tr>
<td>P5, P6, M4, D3</td>
<td>Lessons Learned from Personal Performance in Aircraft First-line Maintenance Operations</td>
<td>Learners review their performance while carrying out workshop inspection and fitting processes, what they have learned and what aspects of their performance could be improved.</td>
<td>The evidence will focus on what went well and what did not go so well when carrying out mechanical and electrical inspection, safe working practices and suitable component selection processes, and a conclusion of improvements that could be made. The portfolio of evidence will be generated while exploring and reviewing aircraft workshop inspection and fitting processes and reflecting on own performance.</td>
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</table>
**Essential resources**

For this unit, learners must have access to:

- appropriate information sources, including relevant maintenance and repair manuals, EASA, CAA or equivalent military publications, workshop safety procedures, notices and safety drills

- a range of consumable parts and related hardware suitable for performing the fitting, installing and repair methods as required by the learning aims and unit content

- hand tools, and pneumatic or electrical power tools, precision measuring equipment, workshop machines and equipment suitable for performing the fitting, installing and repair methods as required by the learning aims and unit content

- electrical circuit boards, test and measurement instruments and cable crimping tools and equipment

- a range of mechanical and fluid system training rigs and selected aircraft structure or a light aircraft suitably equipped to enable fitting, installing and repair methods to take place.
Unit introduction

Gas turbine engines have become the major source of propulsive power for modern-day commercial and military aircraft, due to their superior power output and efficiency savings in relation to their reciprocating piston engine counterparts. Gas turbine engines also encompass all specialist engineering areas and have revolutionised global travel and power production, making them one of the most significant technological advances of the age.

In this unit, learners will examine the scientific principles that underpin the operation of gas turbine engines, including changes to the working fluid as it passes through the main components of the engine. They will compare the function, operation and construction of the different types of gas turbine engine. Next, they will explore the function and operation of the principal components and systems that make up the modern gas turbine engine. Finally, learners will examine the factors that affect the performance and environmental impact of aircraft gas turbine propulsion.

Studying this form of aircraft propulsion is essential if learners want to work in the aeronautical sector. This unit will help to prepare them for an aircraft engineering apprenticeship, as well as helping them to gain employment in an aircraft technician role. Alternatively, learners could choose to continue to study this area in higher education.

Learning outcomes

On completion of this unit a learner should:

1. Examine the scientific principles and operation of aircraft gas turbine engines that produce thrust
2. Examine the function and operation of gas turbine engine components and systems that produce thrust
3. Investigate the factors affecting the performance and environmental impact of aircraft using gas turbine propulsion.
Unit content

1 Examine the scientific principles and operation of aircraft gas turbine engines that produce thrust

Scientific principles relating to gas turbine engines

- The gas laws and the expansion and compression of perfect gases; including Charles’, Boyle’s; and the combined gas law and their parameters.
- Boyle’s law and isothermal expansion and compression, adiabatic (constant heat) expansion and compression.
- The theoretical Brayton gas turbine cycle (including assumptions made), cycle states (adiabatic compression, constant pressure heat addition, adiabatic expansion, constant pressure heat rejection).
- Use of pressure/volume and temperature/volume diagrams.
- The practical working Brayton cycle, including compression, combustion, expansion and induction, losses incurred in comparison with theoretical cycle.
- Newton’s laws and their relationship to aircraft thrust.
- Flight thrust, including:
  - basic net thrust $F_N = \dot{m} (v_j - v_a)$ where $\dot{m}$ = mass flow rate of the air moving rearwards, $v_j$ = is the velocity of the gas stream at exit/exhaust from engine and $v_a$ = the velocity at the engine inlet
  - total net flight thrust (TNFT) (subsonic) = $F_N = \dot{m} (v_j - v_a) + \dot{m}_f v_i$, where $\dot{m}_f$ = mass flow rate of the fuel
- Supersonic flow at propelling nozzle, chocked nozzles:
  - TNFT (supersonic) = $\dot{m} (v_j - v_a) + \dot{m}_f v_i + A(p_c - p_{amb})$
    where $A$ = cross-sectional area of propelling nozzle, $p_c$ = chocked pressure of gas at propelling nozzle, $p_{amb}$ = ambient air pressure.

Types and operation of aircraft gas turbine engines

- Turbojet engines:
  - operation of the common core gas generator, including the function of the compressor, combustor, turbine and exhaust, the temperature, pressure and velocity changes made to the working fluid as it passes through the gas generator components
  - operation of the turbojet engine, including the production of thrust from the working fluid entering the intake, passing through the gas generator and exhausting via the propelling nozzle to the ambient atmosphere, the limitations of the pure turbojet engine
  - construction, arrangement and location of the intake, compressor, combustor, turbine, exhaust, propelling nozzle and associated gearing and connections of a single shaft turbojet engine
  - limitations including use of high velocity exhaust gases for thrust production, noise pollution, reduced propulsion efficiency.
• Turbofan engines:
  - operation, including function of the addition of a high bypass ratio fan and low pressure turbine, the production of thrust and the passage and function of the working fluid through the fan and low pressure turbine
  - construction, arrangement and component location, including the differences between a multi-shaft high bypass turbofan engine and its single shaft turbojet counterpart
  - relative advantages of turbofan engines over turbojets, including fuel efficiency, propulsive efficiency, cooling and noise reduction.

• Turboprop engines:
  - operation of turboprop engines, including the function of the low pressure turbine, gearbox and propeller in the conversion of torque from the drive shaft into thrust from the propeller
  - construction, arrangement and component location, including the addition of a low pressure turbine, main gearbox and propeller, over the core gas generator components
  - relative advantages and disadvantages over turbofan engines, including better power to weight ratio, unsuitability for high speed applications.

• Turboshaft engines:
  - operation of turboshaft engines, including the function of the low pressure turbine and drive shaft to produce torque, the production of thrust for helicopter operation and the passage of the reverse gas flow through the engine
  - construction, arrangement and component location, including the need for a larger diameter drive shaft and more robust compressors and turbines with fewer stages
  - relative advantages, including a range of different industrial applications, e.g. turbomachinery, marine.

2 Examine the function and operation of gas turbine engine components and systems that produce thrust

Function and operation of turbine engine components

• Compressors and fans:
  - function and operation of axial flow compressors, including stage rotors and stators, stage velocities and pressure rises and governing factors, multi-stage compressor pressure and temperature rises, function of variable inlet guide vanes (VIGV) and variable stator vanes (VSV)
  - function and operation of centrifugal compressors, including function of inlet duct and vanes, the impeller, rotating guide vanes and radial diffuser vanes, airflow and pressure rise through the compressor and centrifugal action of the air
  - function and operation of fans, including compression of the bypass air, feeding supercharged air into core, high bypass ratio single stage compression, need for multi-stage fans for military aircraft, form of fan blade, fan disc, attachments and casing.
• **Combustors:**
  o combustor types, including multiple combustion chamber, tubo-annular and annular
  o combustor requirements, including high combustion efficiency, reliable ignition, restart at altitude, low pressure losses, low emissions and high durability
  o function and operation, including velocity control of the combustible gases, factors affecting combustion efficiency, fuel injectors, vaporisers, fuel spray nozzles, igniters and combustion chamber cooling.

• **Turbines:**
  o turbine function and operation, including types – single and multi-stage, impulse and reaction turbines, dependence of energy transfer from gas on – gas mass flow rate, blade speed and swirl velocity change
  o turbine components function and operation, including turbine casing, discs, shafts, nozzle guide vanes (NGV) and blades.

• **Intakes and exhausts:**
  o intakes function and operation, including civil aircraft turbofan short, circular intake design, minimisation of drag at cruise speeds, integration with engine cowlings, necessity for heating and anti-icing features, military-side mounted and under-fuselage and supersonic intakes
  o engine exhausts function and operation exhaust gas propelling nozzles, reverse thrusters, thrust vectoring nozzles for vertical/short take-off and landing V/STOL aircraft.

**Function and operation of engine starter and fluid systems**

• **Starter systems:**
  o starter systems, including starting phase operation from ignition, through dry cranking, acceleration to thermal soak at ground idles, design considerations for hot and cold weather starting, starting methods, e.g. air turbine, electric, gas turbine and cartridge
  o engine starting precautions for personnel, including knowledge and avoidance of engine intake and exhaust danger zones, positioning and handling of fire appliances, radio or other contact with pilot.

• **Fluid systems:**
  o engine air system cooling, including the need and methods used for air cooling turbine blades, NGVs, discs, shafts and casings
  o air system sealing, e.g. labyrinth, brush and leaf, carbon and ring seals and sealing methods
  o airframe fuel system function and operation, including fuel storage, shut-off valves, fuel distribution, booster pumps, manifolds, pipes, bypass and cross-feed valves, fuel system contents, temperature and pressure indications
  o engine fuel system interaction, including fuel system operation from start-up to cruise and descent, fuel filtration, metering and demand control
  o engine oil system function and operation, including full flow and pressure relief systems, spline lubrication methods
3 Investigate the factors affecting the performance and environmental impact of aircraft using gas turbine propulsion

Aircraft gas turbine engine performance

- Measures of performance, including:
  - specific thrust = output thrust/engine inlet mass flow
  - specific power = output power/engine inlet mass flow
  - specific fuel consumption (SFC) = fuel flow rate/output thrust or power, where SFC is measured in kilogrammes of fuel burnt per hour per Newton of thrust or kg/hr/N.

- Effect and implications of gas turbine cycle parameters on performance, including effect of compressor pressure ratio and turbine entry temperature (TET) on SFC and specific thrust or power.

- Effect and implications of thermal efficiency
  \[ \eta_{\text{thermal}} = \frac{\dot{m}}{2(v_j^2 - v_a^2)} \] and propulsive efficiency
  \[ \eta_{\text{prop}} = 2 \frac{\frac{v_j}{1 + \frac{v_j}{v_a}}}{m_f LCV} \]
  on aircraft specific fuel consumption and thrust
  \[ F_N = \dot{m} (v_j - v_a) \] performance of turbojet and high bypass turbofan aircraft,
  where \( m_f \) = mass flow rate of the fuel in kilogrammes per second (kg/s) and \( LCV = \) lower calorific value of the fuel in joules per kg (J/kg).

- Thrust enhancement, including use of variable area nozzles, reheat, water and water/methanol.

Environmental impact of gas turbine engines

- Noise, including:
  - noise measurement and limits, including decibel (dB) rating, noise limit regulation
  - sources of aircraft noise and its reduction, including fan, exhaust jet, low pressure turbine and combustor noise, turbine engine noise testing
  - gas turbine operating emissions and effects on the environment, including health risks from global warming and acid rain.

- Emissions, including:
  - nature and effects of gas turbine emissions, including carbon dioxide (CO₂), water vapour (H₂O), contrails and the production of (H₂O) and sulphuric acid (H₂SO₄), carbon monoxide (CO), oxides of nitrogen (NOₓ) and sulphur (SOₓ) and smoke particulates
  - airport pollution, including emissions monitoring and the effect of the introduction of the standard landing and take-off cycle (LTO)
o Modern gas turbine emission reduction methods, including the control of unburnt hydrocarbons and carbon monoxide (CO), improvements in combustor design, use of high bypass turbofan engines, relationship of top turbine temperature (TTT), engine performance and the production and control of oxides of nitrogen (NOx).
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>explain the application of scientific principles to aircraft gas turbine engine cycles and thrust production</td>
<td>M1 analyse the application of scientific principles to aircraft gas turbine engine cycles and thrust production</td>
<td>D1 evaluate, using vocational and high quality written language, the application of scientific principles to the cycles, operation and thrust production of two types of aircraft turbine engines, making comparisons between types</td>
</tr>
<tr>
<td>P2</td>
<td>explain the operation of two types of aircraft gas turbine engines</td>
<td>M2 analyse the operation of two types of aircraft gas turbine engines, making comparisons between types</td>
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</tr>
<tr>
<td>P3</td>
<td>explain the function and operation of gas turbine engine components</td>
<td>M3 analyse the function and operation of gas turbine engine components and engine starter and fluid systems, making comparison between component types</td>
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<tr>
<td>P4</td>
<td>explain the function and operation of gas turbine starter and fluid systems</td>
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</table>

**P1**

explain the application of scientific principles to aircraft gas turbine engine cycles and thrust production

**P2**

explain the operation of two types of aircraft gas turbine engines

**P3**

explain the function and operation of gas turbine engine components

**P4**

explain the function and operation of gas turbine starter and fluid systems

**M1**

analyse the application of scientific principles to aircraft gas turbine engine cycles and thrust production

**M2**

analyse the operation of two types of aircraft gas turbine engines, making comparisons between types

**M3**

analyse the function and operation of gas turbine engine components and engine starter and fluid systems, making comparison between component types

**D1**

evaluate, using vocational and high quality written language, the application of scientific principles to the cycles, operation and thrust production of two types of aircraft turbine engines, making comparisons between types

**D2**

evaluate the function and operation of gas turbine engine components and engine starting and fluid systems, making comparisons between component type and system types
### Assessment and grading criteria

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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P5</strong> explain, using research, how gas turbine engine performance is measured and improvements in thrust production and fuel efficiency are achieved in turbofan engines</td>
<td><strong>M4</strong> analyse, using research, how gas turbine engine performance is measured and improved using turbofan engines and the methods used to mitigate the effects of aircraft environmental pollutants.</td>
<td><strong>D3</strong> justify, using research, how gas turbine engine performance is measured and improved using turbofan engines and the methods used to mitigate the effects of aircraft environmental pollutants suggesting possible future improvements.</td>
</tr>
<tr>
<td><strong>P6</strong> explain, using research, the nature of environmental pollutants produced from gas turbine engines and the methods used to mitigate their effects.</td>
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</tbody>
</table>
**Essential guidance for tutors**

**Assessment**

For P1, learners will explain the cycles, operation and thrust production in gas turbine engines, using the gas laws to mathematically determine parameters. They will show how Boyle’s law is related to isothermal and adiabatic expansions and compressions in the theoretical Brayton cycle, and use appropriate graphical examples to explain the differences between the theoretical and real cycles.

An explanation of Newton’s laws and their application to basic thrust and total net flight thrust under subsonic and supersonic flight conditions will be included.

For P2, learners will explain the operation of two types of gas turbine engine, clearly indicating how the construction, components and passage of the gases through the engine affect the function and operation of each to produce thrust.

Overall, the evidence will be logically structured but may be basic in parts and contain minor technical inaccuracies, for example omitting or incorrectly identifying some constructional detail of a particular engine. Also, when using the gas laws to mathematically determine parameters, minor arithmetic and scaling errors are acceptable, as are ‘carry through’ errors provided that the basic method is sound. Learners will demonstrate an appreciation of the need for the correct use of units, but there may be errors in their application. There will also be evidence of simple checks to determine if numerical answers are ‘reasonable’.

For P3, learners will explain the function and operation (which includes the principles, features, construction and layout) of intake, compressor, combustor, turbine and exhaust engine components, using qualitative examples to explain the application of scientific principles. For example, to explain the compression ratio of air as it passes through an axial compressor, learners will relate its magnitude qualitatively to the convergent nature of the compressor casing, the number of stages and the mass flow rate of the air.

Learners will explain for P4, the function and operation of engine starting, air, fuel and oil systems as well as the function of the starter and fluid system components.

Overall, the evidence will be logically structured but may be basic in parts and contain minor technical inaccuracies, for example by omitting a minor component in an engine fuel system, or being slightly confused over its function within the system.

For P5, learners will explain, using research, how gas turbine engine performance is measured using specific fuel consumption and specific thrust, and improved by using turbofan engines.

Learners will explain for P6, the nature of the environmental pollutants gas turbine engine operation produces and the methods used to mitigate their effects.

Overall, the evidence will be logically structured but may be basic in parts and contain minor technical inaccuracies. For example, in providing an explanation of the performance improvements achieved using turbofan engines, explanations may be patchy in parts through omitting some minor detail or, where quantitative examples have been given, the process followed may contain some minor arithmetic and scaling errors and 'carry through' errors. These errors are acceptable, provided that the basic method is sound. Learners will demonstrate an appreciation of the need for the correct use of units, but there may be errors in their application. There will also be evidence of simple checks to determine if numerical answers are ‘reasonable’.
For M1, learners will analyse the cycles, operation and thrust production in gas turbine engines, using the gas laws to mathematically determine parameters. They will show how Boyle’s law is related to isothermal and adiabatic expansions and compressions in the theoretical Brayton cycle, and use appropriate graphical examples to assess the differences between the theoretical and real cycles.

A quantitative analysis of Newton’s laws and their application to basic thrust and total net flight thrust under subsonic and supersonic flight conditions will be included.

For M2, learners will compare the operation of two types of gas turbine engine, assessing how changes in the constructional features, components and passage of the gas flow affect the function and operation of each. For example, comparing a turboprop engine with the addition of a gearbox and propeller producing thrust, with a pure turbojet designed to produce thrust using high temperature and high velocity exhaust gases.

Overall, the evidence should be logically structured, technically accurate (including the correct use of mathematical terminology and relevant units) and easy to understand. For example, the numerical work will be to an appropriate degree of accuracy, given the context of the engine being investigated. For example, appropriate significant figures and decimal places.

For M3, learners will analyse the function and operation of intake, compressor, combustor, turbine and exhaust engine components, making comparisons between different types, using quantitative examples where appropriate, to explain their operating principles. For example, when considering the operation of engine exhausts, comparisons could be made between reheat and variable area nozzles as a means of increasing thrust, using quantitative examples involving the gas laws and the supersonic thrust formula to explain their operation.

Learners will analyse the function and operation of engine starting, air, fuel and oil systems, as well as the layout and function of the starter and fluid systems components.

Overall, the evidence should be logically structured, technically accurate (including the correct use of mathematical terminology and relevant units) and easy to understand. For example, the numerical work will be to an appropriate degree of accuracy, given the context of the engine being investigated. For example, appropriate significant figures and decimal places.

For M4, learners will analyse, using research, how gas turbine engine performance is measured using specific fuel consumption, specific thrust and other efficiency measures, and improved by using turbofan engines. Learners will also analyse the nature of the environmental pollutants gas turbine engine operation produces and the methods used to mitigate their effects. For example, learners could analyse how improvements to combustor ignition, fuel injection and control have reduced the amount of unburnt hydrocarbons and carbon monoxide (CO) pollutants.

Overall, the evidence will be well researched, logically structured, technically accurate (including the correct use of mathematical terminology and relevant units) and easy to understand. The numerical results used, for example to illustrate the performance improvements achieved from the use of turbofan engines, will be quoted to an appropriate number of significant figures and decimal places.

For D1, learners will evaluate the cycles, operation and thrust production in gas turbine engines, using the gas laws to mathematically determine the parameters. They will show analytically how Boyle’s law is related to isothermal and adiabatic expansions and compressions in the theoretical Brayton cycle, clearly differentiating between the theoretical and real cycles, using appropriate graphical examples.
A quantitative analysis of Newton’s laws and their application to basic thrust and total net flight thrust under subsonic and supersonic flight conditions will be included.

Learners will compare the two types of gas turbine engine, covering the way in which each type changes the passage of the working fluid as it passes through it and also, collectively, how these changes and differences in their constructional features and components affect function and operation of these engines. Quantitative examples should be used, where appropriate, to show differences in the gas flow parameters through each engine. For example, how the addition of a large fan and low pressure turbine in a high bypass turbofan engine quantitatively changes the mass flow and velocity of gas on its passage through the engine and how in turn this produces high thrust and, comparing this engine with the function and operation of a turboshaft engine designed to produce high torque.

Overall, the evidence presented will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured, use correct engineering terms and will be of a high standard of written language. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions that model engineering situations. Small and large numerical values will be presented correctly in an appropriate format, for example engineering notation or standard form. Learners must demonstrate that they are able to work to an appropriate degree of accuracy, given the type of engine being investigated, through the use of appropriate significant figures.

For D2, learners will evaluate the function and operation of intake, compressor, combustor, turbine and exhaust engine components, comparing the differences in design between component types and the effect these differences have on component and overall engine operational performance. For example, learners could compare the differences in the operational efficiency of a single axial compressor with its separate twin or triple compressor counterpart.

The evaluation should also include an assessment of the function and operation of different engine starter, air, fuel and oil systems, including making comparisons between different types of a particular system and considering the layout and function of system components. For example, by comparing the relative operational advantages/disadvantages between air turbine and electric starting systems.

Overall, the evidence presented will be easy to read, logically structured and well presented. It will also provide a comprehensive, in-depth assessment of the operational differences between component types, using quantitative examples for comparisons, as appropriate. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions that model engineering situations. Small and large numerical values will be presented correctly in an appropriate format, for example engineering notation or standard form. Learners must demonstrate that they are able to work to an appropriate degree of accuracy, given the particular component parameters being investigated, through the use of appropriate significant figures.

For D3, learners will justify, using research, how gas turbine engine performance is measured and improved by the use of turbofan engines. The justification will include an analysis of how high bypass turbofan engines and components help to improve specific fuel consumption, specific thrust and other efficiency measures. Learners will back their analysis up with quantitative examples demonstrating these improvements with the turbofan engine, and by comparing them with their pure turbojet counterpart.
Learners will justify the methods used to mitigate the effects of aircraft pollutants from aircraft turbine engine operation and suggest possible future improvements. For example, quantitatively assessing the relationship between gas turbine entry temperatures, their efficient operation and the release of nitrous oxides into the atmosphere. Learners will assess the nature and feasibility of future improvements, such as operating gas turbine engine aircraft at higher altitudes.

Overall, the evidence will provide a wide-ranging, well-researched justification, which includes the methods used to measure and improve gas turbine performance, and the nature of pollutants and the methods used to mitigate their effects. Evidence will include possible future technical and operational improvements that could be made to further safeguard the environment. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions used to illustrate, for example, the improvements in specific thrust and other efficiency measures achieved by using turbofan engines. Small and large numerical values will be presented correctly in an appropriate format, for example engineering notation or standard form. Learners must demonstrate that they are able to work to an appropriate degree of accuracy through the use of appropriate significant figures.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, M2, D1</td>
<td><strong>Scientific Principles, Types and Operation of Relating Aircraft Gas Turbine Engines</strong></td>
<td>An activity requiring learners to research scientific principles, function and operation of aircraft gas turbine engines.</td>
<td>A report covering the scientific principles, function and operation of two engine types selected from turbojet, turbofan, turboshift and turboprop gas turbine engines.</td>
</tr>
<tr>
<td>P3, P4, M3, D2</td>
<td><strong>Function and Operation of Turbine Engine Components And Starter and Fluid Systems</strong></td>
<td>An activity requiring learners to research the function and operation of aircraft gas turbine engine components and starter and fluid systems.</td>
<td>A report covering the function and operation of aircraft gas turbine engine components, and starting and fluid systems.</td>
</tr>
<tr>
<td>P5, P6, M4, D3</td>
<td><strong>Performance and Environmental Impact of Aircraft Gas Turbine Engines</strong></td>
<td>An activity requiring learners to research the performance of aircraft gas turbine engines, their environmental impact and measures being taken to reduce negative impacts.</td>
<td>A report covering the factors that affect the performance of aircraft gas turbine engines and the nature and measures being taken to help reduce the adverse effects of gas turbine engine pollutants.</td>
</tr>
</tbody>
</table>
Essential resources

Please note that the required physical resources may not necessarily be directly available at the centre delivering the unit but can be made available on the premises of a partner organisation.

For this unit, learners must have access to:

- gas turbine engine(s) with an axial flow compressor, preferably sectioned, capable of allowing access to, or at least sight of, internal components
- gas turbine engine components on or off engine, including centrifugal compressor, can-annular or annular combustors, single and/or multi-stage turbines, exhaust systems with or without reheat
- sight of turboshaft, turboprop and high bypass turbofan engines
- installed engines on a training aircraft, showing intake, engine installation method, engine cowlings and fairings and exhaust
- sight of engine internal fluid systems and components, e.g. air cooling and sealing, oil lubrication, fuel control
- external ancillary equipment and systems, e.g. engine ignition and starter, airframe fuel supply system, auxiliary gearbox.
Unit 11: Aircraft Propulsion System

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

With the increasing range of scheduled aircraft flights, and extended twin-engine operations over greater distances, the reliability and safe operation of the propulsion systems that support the aircraft power plant is essential.

In this unit, learners will examine the function and operation of the major systems and their components associated with the aircraft engine power plant, including the external fuel supply and internal engine fuel distribution systems. They will examine the function and operation of electromechanical and electronic engine control systems. Learners will then examine the function and operation of the engine lubrication and air systems, and their components. Finally, they will examine the function and operation of the fire and ice protection systems and learn how all these systems assist aircraft propulsion.

A study of the aircraft and engine systems that support aircraft propulsion is considered essential if learners want to work in the aeronautical sector. This unit will help to prepare them for an aircraft engineering apprenticeship, or to gain employment in an aircraft technician role. Alternatively, learners could choose to continue their studies in higher education.

Learning outcomes

On completion of this unit a learner should:

1. Examine the function and operation of aircraft fuel and engine control systems that support safe aircraft power plant operation
2. Examine the function and operation of aircraft engine lubrication and air systems that support safe aircraft power plant operation
3. Examine the function and operation of aircraft fire and ice protection systems that support safe aircraft power plant operation.
Unit content

1 Examine the function and operation of aircraft fuel and engine control systems that support safe aircraft power plant operation

Aircraft fuels and fuel supply systems

- Types, function and properties of fuels and fuel additives, including:
  - aviation gasoline (AVGAS)
  - JET A1 (AVTUR), an aviation jet turbine kerosene fuel
  - JET B (AVTAG), a wide-cut jet turbine gasoline/kerosene fuel
  - fuel flash point temperature, auto-ignition temperature and density
  - additives, ice and corrosion inhibitors, antioxidants and anti-static agents.

- Fuel supply system component identification, function and layout, including:
  - fuel storage tanks, rigid, integral, flexible
  - booster, jettison and transfer pumps
  - engine fuel, cross-feed, bypass, vent and jettison valves
  - fuel plumbing, heat exchangers
  - fuel level, temperature and pressure sensors and switches, related cabin/cockpit indications and warnings.

- Fuel system operation, including:
  - fuel engine feed, pressurisation and inerting
  - fuel jettison, venting, refuelling and defuelling.

Engine fuel systems

- Airframe and engine fuel system interaction requirements, including:
  - avoidance of suction operation
  - priming, re-priming and relight facility
  - avoidance of fuel contamination.

- Component identification, function and layout, including:
  - low- and high-pressure fuel pumps
  - low- and high-pressure filter assemblies
  - fuel heaters and heat exchangers
  - fuel drains tank
  - pressure and flow control valves, flow meters
  - fuel manifold and fuel spray nozzles.

- Function and operation of a hydro-mechanical fuel metering unit, including main valve assemblies, inputs and outputs.

- Function and operation of typical engine fuel system, from input at low pressure fuel pump to fuel spray nozzles.
Engine electromechanical and electronic control systems

- Electromechanical engine control systems.
  - Identification, function and layout of engine mechanical control system components and system operation, including:
    - teleflex and bowden cables, tension regulators, turnbuckles, cable control stops, control pulley box, start/thrust cable control drum, feedback cables
    - control rods, eye and fork end fittings
    - cable grommets, pressure seals
    - forward and reverse thrust levers, fuel control levers.
  - Electrically actuated fuel shut-off valves, directional control valves, control switches.
  - Function and operation of auto-throttle, including regulation and switching, flight/ground idle control.

- Electronic engine control systems.
  - Identification and function of typical electronic engine control system components including electronic engine controller, power demand and feedback sensors, fuel pumps and fuel metering controller.
  - Function and operation of a full authority digital electronic control (FADEC) control system, including:
    - electronic engine controller (EEC)
    - FADEC fuel metering unit (FMU), metering control and interaction with EEC
    - FADEC control of, for example, minimum pressure rise, fuel shut-off, over speed shut-off, manifold draining on shut down, pump unloading and fuel return to tank control
    - function and integration of the engine health monitoring (EHM) system with the EEC system.

2 Examine the function and operation of aircraft engine lubrication and air systems that support safe aircraft power plant operation

Engine lubrication systems

- Engine lubricant types and properties, including:
  - mineral-based, diester-based and polyol ester-based oils
  - viscosity, flash point, adhesion and cohesion.
- Oil additive types and function, including anti-foaming agents, thickeners, anti-oxidants.
- Oil identification and grading systems, including:
  - commercial aviation number
  - MIL and AN specification (military)
  - SAE system.
● Functions of engine oil systems including lubrication, cooling, cleaning, corrosion protection.

● Component identification, function and layout, including:
  o oil reservoirs, deaerators
  o constant displacement oil pumps (gear, vane and gerotor), scavenge pumps
  o oil filters, filter ratings
  o chip detectors (indicating and pulsed)
  o relief valves, check valves
  o oil jets, distributors, vents
  o fuel/oil heat exchanger, air/oil cooler
  o pressure and temperature gauges.

● Operation of recirculatory gas turbine engine lubrication systems, including:
  o pressure relief system
  o full flow system
  o pressure feed and distribution, scavenge and vent, sub-systems.

Engine internal air systems

● Functions of gas turbine engine’s air system, including cooling, bearing chamber and flow path sealing, bearing axial load control.

● Function and operation of air cooling system, including:
  o turbine blade and vane convective, film and transpiration cooling
  o turbine disc, shaft and casing cooling.

● Identification, function and nature of air system seals and sealing methods, e.g.:
  o labyrinth, brush and leaf, carbon, ring and hydraulic rotating seals
  o static seals and sealing
  o effects of external bleed air requirements on internal air system.

3 Examine the function and operation of aircraft fire and ice protection systems that support safe aircraft power plant operation

Fire protection systems and components

● Fire detection.
  o Fire detection zones, including engines, auxiliary power unit (APU), jet pipes.
  o Function and operation of fire/overheat detector systems, including:
    - unit detector systems, e.g. thermal switch, thermocouple, inertia switches, crash switches, detector circuit, alarm circuit, test circuit
    - continuous loop detector systems, e.g. Fenwal and Kidde resistance sensing systems, dual-loop systems, pneumatic sensing systems, fire detection control unit.
Function and operation of smoke, carbon monoxide and flame detection systems, including:
- smoke and carbon monoxide detectors, e.g. light refraction, ionisation, electronic, chemical colour change
- flame detectors, e.g. optical infrared, optical ultraviolet.

Nature of flight deck and cabin fire warnings, including location indicators, red lights, claxons, overheat indicators.

Fire extinguishing.

- Classes of fire, including Class A fires involving ordinary combustible materials, Class B fires involving flammable liquids, Class C fires involving energised electrical equipment, Class D fires involving combustible metals.
- Use of on-board and ground extinguishing agents, including carbon dioxide, halogenated hydrocarbons and water.
- Identification, function and layout of on-board fire extinguishing system components, including extinguisher bottles, discharge valves, cartridges, extinguisher plumbing, two-way check valves, bottle pressure and thermal discharge indicators.
- Pilot and automatic operation of a multi-engine fire extinguishing system.

**Ice protection systems**

- Nature and effects of ice formation, including rim ice, glaze ice, hoar frost and snow.
- Operation of ice detector systems, e.g. probes, vanes, intake sensors, electronically activated, mass activated.
- Function and operation of engine intake, cowling and propeller anti-icing and de-icing systems, including electrical resistance heaters, spray mats, engine bleed air and chemical propeller slinger ring systems.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td><strong>P1</strong> explain the function and operation of fuels, fuel supply and engine fuel systems and their components, identifying the contribution of each system to power plant operation</td>
</tr>
<tr>
<td><strong>P2</strong> explain the function and operation of electromechanical and full authority electronic engine control systems and their components, identifying the contribution of each system to power plant operation</td>
</tr>
<tr>
<td><strong>P3</strong> explain the function and operation of an engine’s recirculatory pressure relief and full flow lubrication systems and their components, identifying their contribution to power plant operation</td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4 explain the function and operation of an engine’s internal air system and its components, identifying their contribution to power plant operation</td>
<td>M4 analyse the function and operation of an aircraft fire and engine ice protection system and their components, identifying their contribution to power plant operation.</td>
<td>D3 evaluate the function and operation of an aircraft fire and engine ice protection system and their components, assessing the contribution of each system to efficient power plant operation.</td>
</tr>
<tr>
<td>P5 explain the function and operation of an aircraft fire protection system and its components, identifying their contribution to power plant operation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P6 explain the nature of ice formation and the operation of engine ice protection system and its components, identifying their contribution to power plant operation.</td>
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<td></td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will explain the function and properties of fuels and fuel additives, the function and operation of an airframe fuel supply system and engine fuel system and their components, identifying the effect each of these systems have on safe power plant operation. For example, learners will explain how the operation of the engine fuel system and the function of its components that ensure a safe fuel supply to the engines, result from the pilot's throttle settings.

For P2, learners will explain the function and operation of electromechanical control, FADEC systems and components, identifying the effect each system has on safe power plant operation. The explanation will include the operation of an electromechanical system and the function of its components used to control pilot throttle inputs, fuel flow and pressure and auto throttle regulation. In addition, the operation of a FADEC system, the function of its components and an EHM system, will be explained.

Overall, the evidence should be logically structured but may be basic in parts and contain minor technical omissions or inaccuracies. For example, learners missing or incorrectly identifying one or two of the functions of the EEC or FMU, when explaining the FADEC engine control system.

For P3, learners will explain the types, requirements and characteristics of engine lubricating oils, the function and operation of aircraft recirculatory engine internal relief valve and full flow lubrication systems and their components, and identify the contribution made by each of these systems and their sub-systems to safe power plant operation. For example, when examining a full flow lubrication system, the function and operation of the pressure feed and distribution, scavenge and vent sub-systems will be explained and their contribution to the safe operation of the lubrication system, identified.

For P4, learners will explain the function and operation of a gas turbine engine’s internal air system and its components, and identify the contribution it makes to safe power plant operation. The analysis will include the function and operation of turbine cooling, airflow seals and sealing, bearing axial load control, equipment cooling and external services bleed air feeds. For example, when examining the operation of the turbine air cooling system, the function and operation of the turbine blade, disk and casing cooling and sealing methods, will be explained and the contribution made by the engine turbine cooling system to the safe operation of the power plant, will be identified.

Overall, the evidence should be logically structured but may be basic in parts and contain minor technical omissions or inaccuracies. For example, learners may miss or incorrectly identify a particular seal or sealing method, when explaining the seals and sealing method in a turbine cooling system.

For P5, learners will explain the operation of fire detection and extinguishing systems and the function of their components, and identify the systems contribution to safe power plant operation. The analysis will include the nature and use of extinguishing agents, the function and operation of fire, heat and smoke detection systems, flight deck and cabin fire warnings and fire extinguishing systems. For example, when examining an engine and jet pipe fire wire detection and extinguishing system, learners will explain the function of the fire wire and control components, the nature of the cabin warning indications, together with the manual and automatic actuation of the extinguisher bottles. The contribution the system makes to the safe operation of the power plant will also be identified.
For P6, learners will explain the operation of ice protection systems and the function of their components, and identify the systems contribution to safe power plant operation. The nature and effects of ice formation and the operation of ice detection, engine intake, cowling and propeller anti-icing and de-icing systems and the function of their components, will be explained.

For example, when examining an electrical resistance cowling heater anti-icing system, the operation of the system, learners will explain the function of the ice detectors and heaters, and the nature of the cabin warnings. The contribution of the anti-icing system to the safe operation of the power plant will also be identified.

Overall, the evidence should be logically structured but may be basic in parts and contain minor technical omissions or inaccuracies. For example, learners incorrectly identifying the priority of the cabin fire or icing warning.

For M1, learners will analyse the function and properties of fuels and fuel additives, the function and operation of an airframe fuel supply system and an engine fuel system and their components, identifying the effect each of these systems have on safe power plant operation. For example, learners’ analysis will include the operation of the engine fuel system pumps, control valves and hydromechanical FMU to ensure a safe fuel supply to the engines that result from the pilot’s throttle settings.

For M2, learners will analyse the function and operation of electromechanical control, and FADEC systems and components, identifying the effect each of these systems have on safe power plant operation. The analysis will include the function and operation of electromechanical and hydro-mechanical system components to control pilot throttle inputs, fuel flow and pressure and auto throttle regulation. In addition, the function and operation of the FADEC system and components including, the engine electronic controller, the FMU and the integration of the EHM system with the FADEC system, will be analysed.

Overall, the evidence will be logically structured, technically accurate and easy to understand.

For M3, learners will analyse the function and operation of aircraft recirculatory engine internal relief valve and full flow lubrication systems and their components, and identify the contribution made by each of these systems to safe power plant operation. The types, requirements and characteristics of engine lubricating oils, the function and operation of the pressure feed and distribution, scavenge and venting sub-systems and their components, will be analysed. For example, when examining the operation of the pressure feed and distribution sub-system, learners will identify the function and operation of the reservoir, filters and heat exchanger components and their contribution to the safe operation of the engines recirculatory lubrication system.

Learners will analyse the function and operation of a gas turbine engine’s internal air system and its components, and identify the contribution it makes to safe power plant operation. The analysis will include the function and operation of turbine cooling, airflow seals and sealing, bearing axial load control, accessory equipment cooling and external services bleed air feeds. For example, when examining the function and operation of the gas turbine air cooling system, the turbine construction, airflow pathways, sealing and cooling methods will be analysed. Learners will also identify the contribution of the turbine air cooling system to the safe and efficient operation of the power plant.

Overall, the evidence will be logically structured, technically accurate and easy to understand.
For M4, learners will analyse the function and operation of fire detection and extinguishing systems and their components, and identify the systems contribution to safe power plant operation. The analysis will include the nature and use of extinguishing agents, the function and operation of fire, heat and smoke detection systems, flight deck and cabin fire warnings and fire extinguishing systems. For example, when examining an engine and jet pipe unit detection and extinguishing system, learners will analyse the function and operation of the detectors, the nature of the cabin warnings, together with the manual and automatic actuation of the extinguisher bottle. The contribution the system makes to the safe operation of the power plant, will also be identified.

Learners will analyse the operation of ice protection systems and the function of their components, and identify the systems contribution to safe power plant operation. The nature and effects of ice formation and the operation of ice detection, engine intake, cowling and propeller anti-icing and de-icing systems and the function of their components, will be analysed. For example, when examining an electrical resistance cowling heater anti-icing system, learners will analyse the operation of the ice detection, control and warning and heater systems and the function of their components. The contribution of these systems to the safe operation of the power plant, will also be identified.

Overall, the evidence will be logically structured, technically accurate and easy to understand.

For D1, learners will provide a balanced evaluation of the function and properties of fuels and fuel additives, the operation of an airframe fuel supply system, its interaction with the engine fuel system and its components, assessing the effect of the combination of these systems on safe and efficient power plant operation. For example, learners will evaluate the interaction between the pilot's throttle input and the operation of the engine fuel pumps, control valves and hydro-mechanical FMU, ensuring a safe and efficient supply of fuel to the engine for all power settings.

Learners will provide a balanced evaluation of the function and operation of electromechanical control, and FADEC systems and components and will assess the combined contribution of the systems. The evaluation will include the function and operation of electromechanical and hydromechanical system components to control pilot throttle inputs, fuel flow and pressure and auto throttle regulation. In addition, the function and operation of the FADEC system and components, including the EEC, the FMU and the integration of the EHM system with the FADEC system, and the relative merits between electromechanical and FADEC engine control systems, will be evaluated.

Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer. The evidence will be logically structured, use correct engineering terms and the written language will be of a high standard.

For D2, learners will evaluate the function and operation of aircraft recirculatory engine internal relief valve and full flow lubrication systems and their components, and the assessment of the contribution made by each of these systems to safe and efficient power plant operation. The types, requirements and characteristics of engine lubricating oils, the function and operation of the pressure feed and distribution, scavenge and venting sub-systems and their components, and the relative merits between the relief valve and full-flow recirculatory lubrications systems, will be evaluated. For example, when examining the pressure feed and distribution and scavenge sub-systems and their components, the relative merits between scavenge pump sizing and pressure feed for both internal relief and full-flow lubrication systems, will be evaluated.
Learners will evaluate the function and operation of a gas turbine engine's internal air system and its components, and assess the contribution it makes to safe power plant operation. The evaluation will include the function and operation of turbine cooling, airflow seals and sealing, bearing axial load control, accessory equipment cooling and external services bleed air feeds. For example, learners will evaluate the airflow pathways, turbine blade, disk and casing design, turbine sealing and cooling methods and the contribution of the turbine air cooling system to the safe and efficient operation of the power plant.

Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer.

For D3, learners will evaluate the function and operation of fire detection and extinguishing systems and their components, and assess their contribution to safe and efficient operation of the power plant. The evaluation will include the function and operation of fire, heat and smoke detectors, flight deck and cabin fire warnings, fire extinguishing bottles, igniter heads and discharge pipes, and the nature and use of extinguishing agents.

For example, when examining an engine bay fire wire detection and extinguishing system, the operation of the fire wire detector, its control and warning circuitry, together with the manual and automatic actuation and prioritisation of the extinguisher bottles will be evaluated. Learners will also assess the contribution of the system and its components to the safe and efficient operation of the power plant.

Learners will evaluate the function and operation of ice protection systems and their components, and assess their contribution to safe and efficient operation of the power plant. The nature and effects of ice formation and the function and operation of ice detectors, engine intake, cowl ing and propeller anti-icing and de-icing systems and their components, will be evaluated. For example, when examining the function and operation of a hot air pre-emptive intake anti-icing system, the operation of the ice detector, its control and warning system and the compressor bleed hot air system, will be evaluated and their contribution to the safe and efficient operation of the power plant, assessed.

Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer. The evidence will be logically structured and use correct engineering terms and will be of a high standard of written language. In particular, the evaluation will cover concisely and consistently the function and operation of fire and ice protection systems and their components, assessing the combined contribution of these systems to safe and efficient power plant operation.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<th>Assessment method</th>
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<tbody>
<tr>
<td>P1, P2, M1, M2, D1</td>
<td>Aircraft Fuel and Engine Control Systems</td>
<td>An activity requiring learners to research aircraft fuel and engine control systems.</td>
<td>A report covering the properties of aircraft fuels, the function and operation of aircraft fuel supply systems, engine fuel and control systems and their components, and their contribution to power plant operation.</td>
</tr>
<tr>
<td>P3, P4, M3, D2</td>
<td>Engine Lubrication and Internal Air Systems</td>
<td>An activity requiring learners to research engine lubrication and internal air systems.</td>
<td>A report covering the nature of aircraft engine lubricants, the function and operation of engine lubrication and internal air systems and their components, and their contribution to power plant operation.</td>
</tr>
<tr>
<td>P5, P6, M4, D3</td>
<td>Aircraft Fire and Ice Protection Systems</td>
<td>An activity requiring learners to research aircraft fire and ice protection systems.</td>
<td>A report covering the function and operation of aircraft fire and ice protection systems and their components, and their contribution to safe aircraft power plant operation.</td>
</tr>
</tbody>
</table>


Essential resources

For this unit, learners must have access to the following specialist physical resources:

- an aircraft gas turbine engine cutaway or otherwise, which includes sight of external and internal lubrication, fuel, control and air systems and components
- a training aircraft or otherwise with installed power plant complete with:
  - intake, cowls and fairings and/or pod, fan, propeller, as available
  - sight of intake and engine fire and ice protection systems and components
  - sight of aircraft engine fuel supply system and components
- data books, manufacturers’ specifications and servicing manuals
- appropriate textbooks.

Please note that some or all of the required physical resources identified above may not necessarily be directly available at the centre delivering the unit but will be made readily available on the premises of a partner or other related organisation.
Unit 12: Airframe Construction and Repair

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Modern commercial aircraft are required to carry as many passengers or as much freight as possible to distant destinations safely and reliably. The airframe is the mechanical structure of an aircraft and it comprises the fuselage, wings, empennage (tail) and undercarriage (the last component is not covered in this unit). To achieve this, the aircraft manufacturer must make use of innovative airframe design and construction methods. For example, 50 per cent of the airframe of the Boeing 787 is built from composite materials yielding a 20 per cent weight saving compared to more traditional designs.

In this unit, learners will gain an understanding of the structural components and methods used to build an airframe. They will explore the inspection and repair procedures needed to ensure that the aircraft airframe remains airworthy. Finally, learners will develop their practical skills by performing an aircraft structural inspection and repair activity in a workshop environment.

As an aeronautical engineer, it is important that learners understand the construction of an airframe and develop practical skills to inspect and repair them. This unit will help to prepare them for an aircraft engineering apprenticeship, as well as aircraft engineering technician roles in aircraft manufacture, maintenance and repair. Alternatively, the unit will help to prepare learners for higher education and progression to other aeronautical engineering courses.

Learning outcomes

On completion of this unit a learner should:

1. Examine the construction and protection methods used to ensure airworthiness of airframe structures
2. Examine how inspection and repair methods are used in the maintenance of composite airframes and components
3. Carry out processes to inspect and repair safely an airframe composite structure or components that will help to ensure airworthiness.
Unit content

1 Examine the construction and protection methods used to ensure airworthiness of airframe structures

Construction and assembly of major airframe structures

- Assembly of fuselage structures, including:
  - skin
  - frames, formers and longerons
  - pressure bulkheads
  - fuselage sections
  - wing, stabiliser, pylon, arrestor gear, and undercarriage/landing gear attachments.

- Assembly of wing structures, including:
  - stressed skin
  - stiffeners, spars, ribs, milled, etched, integral
  - wing boxes, torsion boxes
  - integral fuel tanks
  - composite bonding
  - assembly of landing gear attachment, pylon, control surfaces and high lift/drag devices.

- Assembly of empennage structures, including:
  - fin – vertical stabiliser and rudder
  - tailplane – horizontal stabiliser and elevators.

- Assembly methods including riveting, bolting and bonding.

Structural considerations for airworthiness

- Airworthiness requirements for structural strength to include: structural classification of primary, secondary and tertiary, as defined in the aircraft structural repair manual.

- Zonal and station identification systems, including:
  - the zone system used to identify different areas of the aircraft
  - station identification systems used to locate structural elements on the aircraft relative to a reference point of station 0.

- Design concepts, including:
  - failsafe, safe life and damage tolerant structures
  - drains and ventilation provision to protect against deterioration, including weathering, corrosion and abrasion
  - lightning strike protection provision for airframe, fuel and avionics.

- Airframe symmetry and alignment checks that are generally made after hard landings, abnormal loads or certain maintenance procedures to ensure airworthiness, e.g. wing dihedral angle, wing incidence angle, symmetry check.
Corrosive protection measures, including:
  - materials selection to inhibit corrosion to include: galvanic action, active and passive materials
  - jointing compounds
  - drain holes
  - stringer design
  - protection methods, including chromating, anodising, painting and surface cleaning.

2 Examine how inspection and repair methods are used in the maintenance of composite airframes and components

Adhesives and sealants

- General types of adhesive, including thermoset and thermoplastic polymers, elastomers, epoxy resins, phenolic resins and redux.
- Adhesive safety and service conditions as defined in the material safety data sheet (MSDS).
- General types of sealant, including silicones, bedding sealants, Thiokol (PRC), room temperature vulcanising (RTV) sealants, Proseal PR 1440.
- Use and characteristics of adhesives and sealants, including heat activated, solvent activated, impact activated, solvent cement.

Bonding methods

- Pre-treatments and surface preparation, including:
  - moisture removal by heating
  - potting surface of adherents
  - solvent wipe for cleaning to remove contaminants
  - surface roughening to improve adhesion.
- Curing, including moisture curing, ultraviolet light, anaerobic reaction and anionic curing (cyanoacrylates).
- Bonding safety and service conditions as defined in the MSDS.

Defect types and inspection

- Cause and identification of typical defects, including structural impact, foreign object, surface, delamination, disband, void, contamination and water ingress.
- Inspection methods and procedures, including:
  - tap test for detection of delamination problems
  - visual inspection to identify damage, e.g. dent, penetration, abrasion
  - non-destructive inspection, e.g. thermography, acoustic emission, ultrasonic, radiography (x-ray or gamma-ray).
Repair procedures

Non-patch and patch repairs, including:

- resin injection (potting or filling)
- delamination injection, heat treatment
- surface coating bonded external patch
- bonded scarf
- bonded flush
- repair curing using the hot bonder or autoclave
- bolted external patch.

Safe working practices for repairing airframe composites

- Key features of health and safety regulations, or other relevant international equivalents, including:
  - Control of Substances Hazardous to Health (COSHH) Regulations 2002 and amendments, e.g. requirements on the safe storage and use of hazardous substances, manufacturers’ safety data sheets, hazard symbols, ventilation, protection from contact with hazardous substances (e.g. methyl-ethyl-ketone, acetone)
  - Personal Protective Equipment (PPE) at Work Regulations 1992 and amendments, e.g. employer responsibility to provide appropriate equipment; e.g. eye protection, barrier creams, disposable gloves, protective clothing, dust masks, respirators
  - Manual Handling Operations Regulations (MHOR) 1992 and amendments – avoid the need for manual handling, types of hazard, assess risk of injury when manual handling is required, control and reduce the risk of injury, training in use of aids
  - Procedures, hazards and precautions when working at height (Working at Height Regulations 2005 and amendments) and working in confined spaces, e.g. under mechanical systems.

- Other safe working practices, including material data sheets, health and safety procedures, reporting of hazardous items of plant or equipment, and emergency procedures.

- Safety hazards, including dust, solvents, handling materials (e.g. composite sheets and resins), ultraviolet light and high temperatures.
3 Carry out processes to inspect and repair safely an airframe composite structure or component that will help to ensure airworthiness

**Inspection of airframe damage**

- Structural classification of damaged component, e.g. primary, secondary.
- Approved repair information, e.g. structural repair manual, authorised repair drawings.
- Preliminary survey of damage to determine size/depth of area needing repair.
- Removal of damaged materials.
- Repair report detailing the results of the survey and scope of damage.
- Damage classification (as defined in the Structural Repair Manual for the target aircraft), including:
  - allowable, where the damage is within the limits defined in the Structural Repair Manual and the aircraft may return to service until a permanent repair is made, e.g. removing dents, stop-drilling cracks, polish scratches
  - repairable by patching, e.g. skin or fuselage repair
  - repairable by insertion, e.g. potting repair
  - repairable by replacement, e.g. honeycomb core repair
  - repair limits for cracks, skin panting, bow and dents.
- Procedural points and safety issues to be considered during repair work, including:
  - inspection of rivet/bolt holes for elongation or deformation
  - inspection before closing work
  - repair material compliance
  - removal of swarf and burrs
  - need for jury rigging.
- Assessment of composite structures for damage and damage limits.

**Structural repair manual**

- General familiarity and limitations.
- ATA 100 specification.
- Numbering system (chapter, section, subject, figure).

**Preparation procedures for the repair of airframe composite structures**

- Consulting information sources to determine airframe composite structure inspection and repair processes, including standards.
- Identifying and selecting, from information sources, all required consumables and hardware components for designated composite structure inspection and repair activity.
- Complying with laid down processes, including tests and inspection checks for designated composite structure repair activity.
Airframe composite structure inspection and repair processes

- Safe working practices, e.g. the use of PPE.
- Carry out repair using processes identified from information sources.
- Repair of minor damage, e.g. scratches, pits, dents, small blisters and minor delamination.
- Typical multi-lamination repairs and repairs to honeycomb core and one or both skins.
- Curing repairs.
- Quality control checks, including:
  - repair activities in compliance with information sources procedure
  - inspection checks, including visual, physical, e.g. tap test and non-destructive tests (e.g. ultrasonic).
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
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<th></th>
</tr>
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<tbody>
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<td>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</td>
</tr>
<tr>
<td><strong>P1</strong> explain the typical construction and assembly methods used for major airframe structures</td>
<td><strong>M1</strong> compare the typical construction and assembly methods used for major airframe structures and explain the structural considerations that apply to them, helping to ensure airworthiness</td>
</tr>
<tr>
<td><strong>P2</strong> explain what airframe structural considerations apply to an aircraft, helping to ensure airworthiness</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> explain the procedures for the inspection of damage to composite structures and components</td>
<td><strong>M2</strong> analyse what inspection and repair methods would be effective for the detection and repair of damage to a given airframe composite structure or component</td>
</tr>
<tr>
<td><strong>P4</strong> explain the procedures and related safety precautions for patch and non-patch repairs to composite structures and components</td>
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### Assessment and grading criteria

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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
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<tr>
<td><strong>P5</strong> inspect a composite airframe structure or component for damage, classify the type of damage and identify an appropriate repair method</td>
<td><strong>M3</strong> complete the repair of a damaged airframe composite structure or component safely and accurately, including appropriate inspections, checks and tests.</td>
<td><strong>D3</strong> refine, during the process, the repair to a damaged airframe composite structure or component safely to ensure airworthiness and integrity, including appropriate inspections, checks and tests.</td>
</tr>
<tr>
<td><strong>P6</strong> complete the preparation activities to repair a damaged composite airframe structure or component effectively</td>
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<tr>
<td><strong>P7</strong> Repair a damaged composite airframe structure or component safely, including appropriate inspections, checks and tests.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will provide in their evidence an explanation of the construction and assembly of major mechanical airframe structures. For example, the fuselage of an A320 is constructed from composite materials and assembled in sections and joined together with rivets. The explanation will cover the main components, construction and assembly methods used in a typical airframe.

For P2, learners will explain the key structural considerations for airworthiness. For example, learners will explain why galvanic protection is important for mating metal structural components and which type of metals can be in contact with each other.

Overall, the evidence will be logically structured. The evidence may be basic in parts, for example making general statements about the assembly methods for airframe structures, and may contain technical inaccuracies or omissions, such as an assembly method described as riveted when bolted is correct.

For P3 and P4, learners will include in their evidence an explanation of the procedures for the inspection and repair of damage to airframe composite structures and components. For example, that a tap test can be used to detect delamination of a composite structure and a patch repair would normally be required to ensure the airworthiness of the structure with this type of damage.

Overall, the explanations will be logically structured, although basic in parts and they may contain minor technical or diagrammatic errors. For example, the explanation of a scarf patch repair may omit the number, type of layers and/or steepness.

For P5, learners will inspect a damaged composite airframe structure or component, classifying the type of damage and identifying the appropriate repair method. For example, visual and/or non-destructive test inspection to determine the extent of impact damage to a composite skin panel leading to a patch repair of the damaged area.

For P6, learners will prepare for the repair by researching the appropriate procedure and selecting appropriate consumables and hardware components and, for P7, will repair the damaged airframe structure or component using the correct procedure. For example, to repair impact damage to a composite skin panel, learners will follow the procedure defined in the SRM. If this is not available the basic steps would be remove damaged material, select appropriate personal protective equipment, prepare surface for either bolting or bonding, apply patch ensuring adequate ventilation, inspect and document repair.

Overall, the correct repair procedure will have been followed but there may be minor errors in accuracy of the finished structure or a void or inclusion may be detected during the final inspection process.

For M1, learners will compare in their evidence the construction and assembly of major airframe structures, demonstrate a clear understanding of the assembly processes. For example, the horizontal stabiliser on the Airbus A320 tailplane is constructed from composite materials because of the high strength and relatively low weight of the materials, but it could equally have been made from metallic materials. Learners will also explain the structural considerations that apply to major airframe structures, for example the Airbus A340 rear pressure bulkhead.

Overall, the evidence should be logically structured, technically accurate and easy to understand.
For M2, learners will clearly analyse in their evidence the effectiveness of the available inspection and repair methods in detecting and repairing damage in the given airframe composite structure or component. For example, a visual inspection of the extent of impact damage to a composite skin panel, leading to a bonded/bolted patch repair and final post repair visual and non-destructive testing inspection.

Overall, the evidence should be logically structured, technically accurate and easy to understand.

For M3, learners will complete the repair process safely and accurately. The required accuracy of the inspection and repair will be determined by the standards. For example, correct location of the patch over the damaged area, layout and number of fastener holes as defined in the SRM, correct finish (such as sanded, primed, and painted), and lightning protection mesh installed if required.

Overall, the evidence should be logically structured, be technically accurate and easy to understand.

For D1, learners will provide in their evidence a balanced and thorough justification for the construction and assembly of airframe mechanical structures and of structural considerations that apply. For example, the Airbus A380 centre wing box is a major airframe structure which will weigh around 8.8 tonnes of which 5.3 tonnes is composite materials and provides the link between the wings and fuselage.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured and use correct technical engineering terms and will be of a high standard of written language, for example it will be grammatically correct.

For D2, learners will clearly support in their evidence the selection of inspection methods for the given damaged structure. For example, the considerations that need to be taken into account when making the choice between a bonded or bolted patch repair for impact damage to a composite skin panel, pre-repair inspection to determine the extent of damage and post repair inspection to ensure airworthiness. Learners will also provide a detailed, technically accurate justification of the repair method.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer.

For D3, learners will refine what they are doing throughout the inspection and repair process to ensure the airworthiness and structural integrity of the airframe or component. The airworthiness and structural integrity will be determined by inspecting the finished airframe structure or component for dimensional accuracy and effectiveness of the process. For example, the repair should meet the specification defined in the SRM. In the case of a bolted repair all fasteners and the patch itself should be sealed to prevent water/moisture intrusion, galvanic corrosion or fuel leaks.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer. There will be a comprehensive record of the safety and operational procedures followed, together with accurately and correctly completed documentation for each of the maintenance operations completed.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, D1</td>
<td>Airframe Structures: Construction and Assembly Methods and Structural Considerations</td>
<td>An activity requiring learners to research airframe structures.</td>
<td>A report covering the construction and assembly methods of major airframe structures, such as the fuselage and wings. Also, the structural concepts and corrosion protection methods to ensure airworthiness.</td>
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<tr>
<td>P3, P4, M2, D2</td>
<td>Airframe Inspection and Repair Methods</td>
<td>An activity requiring learners to research aircraft inspection and repair methods.</td>
<td>A report covering the inspection and repair procedures used for the maintenance of aircraft composite structures and components.</td>
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<tr>
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</tr>
<tr>
<td>P5, P6, P7, M3,</td>
<td>Inspect and Repair of a Damaged Airframe Composite Structure</td>
<td>Learners carry out practical inspection and repair activities.</td>
<td>A practical workshop task to safely undertake the inspection and repair of damage to a composite airframe structure. Evidence will include finished repair, observation records/witness statements, annotated photographs and drawings and a completed record of the quality control measures needed to complete the repair process.</td>
</tr>
<tr>
<td>D3</td>
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</table>
Essential resources

Please note that the required physical resources may not necessarily be directly available at the centre delivering this unit, but could be made available on the premises of a partner organisation.

For this unit, learners must have access to:

- a range of aircraft airframe composite structural components
- physical examples of corroded airframe structures or structural components
- aircraft adhesives, sealants, composite materials and composite airframe components
- specialist repair manuals, maintenance manuals and related inspection procedures and other documentation.
Unit 13: Airframe Mechanical Systems

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

When aircraft take-off, they require an undercarriage; wheels and brakes to accelerate along the runway until they are airborne. Once in flight, aircraft are manoeuvred using flight controls, fuel is continuously supplied to the engines, people are kept safe and comfortable in a pressurised air-conditioned cabin and safe flight is maintained no matter what the weather or emergency situation. These essential services help ensure the safety of the aircraft and passengers in flight.

In this unit, learners will apply skills and understanding to the function and operation of airframe mechanical systems. They will explore hydraulic power supplies and the power they provide for the operation of aircraft-landing gear and flight-control systems. They will examine the pneumatic, cabin-conditioning, pressurisation and protection systems that control the cabin environment. They will also examine the construction and operation of the airframe fuel system that ensures a continuous supply of fuel to the engines. Finally, learners will examine the construction and operation of ice-protection and fire-protection systems.

This unit will help to prepare learners for an aircraft engineering apprenticeship; it can also help them to find work as an aircraft technician. Alternatively, they could choose to continue their studies in higher education.

Learning outcomes

On completion of this unit a learner should:

1 Investigate how the operation of hydraulic-power, landing-gear and flying-control systems contribute to safe flight
2 Examine how the operation of cabin environmental control and protection systems contribute to the protection of passengers and crew
3 Examine how the operation of airframe fuel, ice- and fire-protection systems contribute to safe flight.
Unit content

1 Investigate how the operation of hydraulic-power, landing-gear and flying-control systems contribute to safe flight

Hydraulic-power systems and components

- Hydraulic transmission, including:
  - transmission of fluid pressure, fluid force and Pascal’s law
  - fluid types and properties, including vegetable, mineral- and ester-based oils, fluid identification, sources and consequences of fluid contamination
  - fluid-system requirements, including direction and flow control, fluid storage, conditioning and filtration.

- Hydraulic power-supply systems and components:
  - power source function and layout, including:
    - hand pumps, engine-driven pumps, electric pumps
    - emergency provision, e.g. multiple-system provision, Ram Air Turbine (RAT) driven pumps, standby pumps
  - identification, function and layout of fluid storage, control, conditioning and actuation components, including:
    - reservoir safety features and fluid conditioning components, diaphragm and piston accumulators
    - fluid plumbing, pipes (rigid and flexible), hoses, seals and fittings
    - directional control valves, restrictor valves, non-return valves, cut-out valves
    - temperature and pressure control valves, heat exchangers
    - linear and rotary actuators
  - operation of hydraulic power supply systems, including:
    - the provision of a supply to the hydraulic services, under normal and emergency conditions
    - the nature of the hydraulic panel indications and warnings under normal and emergency supply conditions.

Landing-gear systems and components

- Identification, function and layout of landing gear and retardation components, including:
  - single- and multi-bogies, doors, fairings
  - oleo and liquid spring shock absorbers, hydraulic actuators
  - wheels, bearings and tyres
  - brake unit, liners, adjusters, rotors, stators
  - anti-skid devices, e.g. hydro-mechanical, hydro-electronic
  - steering mechanisms and actuators.
● Function and operation of extension/retraction system, including:
  o hydraulic directional control and sequencing, e.g. relief valves, shuttle valves, sequence valves
  o cockpit/cabin indications and warnings
  o emergency provision, e.g. blow-down, hand pump, multiple hydraulic supplies, accumulators.

Mechanically and hydraulically powered flight control systems
● Function and operation of mechanical flight control systems and identification, function and layout of system components, including:
  o control rod and cable systems for operation of primary controls, trim and balance tabs, controls rigging
  o control rods and cables, eye and fork end fittings, bell-crank levers, cable pulleys, fairleads, tension regulators and spring feel units.
● Function and operation of hydraulically powered flying-control systems and identification, function and layout of system components, including:
  o primary controls, aileron, tailplane, elevator, rudder
  o lift augmentation systems, flap and slat
  o lift-reduction systems, lift dumper, spoiler, speed brakes
  o ancillary systems, e.g. artificial feel, Mach-corrected trim, stall control protection and warning, rudder limiter and gust locks.

2 Examine how the operation of cabin environmental control and protection systems contribute to the protection of passengers and crew

Cabin environmental control systems and components
● Pneumatic-supply systems:
  o function of pneumatic supplies, including air-conditioning and pressurisation, thermal anti-icing, engine starting, hydraulic reservoir pressurisation, door and canopy sealing, pitot-static system
  o identification, function and layout of supply system components, including:
    – gas turbine engine and auxiliary power unit (APU) bleed air supplies
    – piston engine air compressor, blower and receiver supplies
    – ram air supplies
    – ground cart
    – supply control via ducts, louvres, channelling, trunking, check valves, pressure control valves.
● Cabin air-conditioning and pressurisation systems and components:
  o identification function and layout of cabin conditioning components, including:
    – mixing and plenum chambers and ducting
    – filters, humidifiers, water separators, diffusers, recirculation fans
    – conditioning pack, pre-cooler, cold-air unit, intercooler
    – mixing valves, duct stats, temperature control valves
o operation of air-conditioning system, including supply, temperature and humidity control and recirculation of conditioned air

o identification, function and layout of cabin pressurisation components, including:
  – pressure controllers, e.g. pneumatic, electrical and discharge valves
  – inward and outward relief valves, warning and indicating devices

o Operation of cabin pressurisation system, including:
  – cabin pressure control cycles (e.g. pneumatic, electrical)
  – cabin air discharge methods
  – emergency provision, warnings and indications.

Cabin protection systems

● Function and operation of aircraft oxygen systems, including:
  o crew and cabin therapeutic walk-round oxygen bottles
  o cabin and crew oxygen storage, distribution and regulation
  o emergency drop-down masks control and provision, e.g. pilot control, altitude switches, bottles, ring main supply, chemical generation.

● Identification, function and layout of cabin and crew equipment, including:
  o safety equipment, e.g. harnesses, seat belts, parachutes, personal equipment connectors
  o emergency equipment, e.g. cabin emergency notices and warning signs, doors and exits, air-stairs, lighting, inflatable passenger slides, smoke detectors, life jackets.

3 Examine how the operation of airframe fuel, ice- and fire-protection systems contribute to safe flight

Airframe fuel systems and components

● Fuel types and properties, including:
  o aviation gasoline (AVGAS)
  o JET A1 (AVTUR) an aviation jet turbine kerosene fuel
  o JET B (AVTAG) a wide-cut jet turbine gasoline/kerosene fuel
  o fuel flash point temperature, auto-ignition temperature and density.

● Type and function of fuel additives, including ice and corrosion inhibitors, antioxidants, anti-static agents.

● Fuel system component identification and function, including:
  o fuel-storage tanks, rigid, integral, flexible
  o booster and transfer pumps
  o transfer, non-return and vent valves
  o fuel plumbing, heat exchangers
  o fuel quantity sensors, e.g. float, capacitance probes, solid state
  o fuel gauges, warning and indicating devices.
● Fuel-tank layout, e.g. wing inboard and outboard tanks, fuselage tanks, ventral tanks, longitudinal balance fuel system and trim tanks.

● Fuel system operation, including:
  o fuel engine feed, pressurisation and inerting
  o fuel jettison, venting, refuelling and defuelling
  o fuel transfer, e.g. engine and auxiliary power unit (APU) feed, inter-tank, re-fuel and de-fuel.

**Aircraft anti-icing and de-icing systems**

● Ice formation, rim ice, glaze ice and Hoare frost, effects of ice and snow.

● Ice detection, e.g. probes, vanes, electronically activated, mass activated.

● Function and operation of pre-emptive anti-icing systems, including:
  o electrical, e.g. pitot probe, fuel vent and windscreen electrical heaters, propeller graphite electrical resistance heaters
  o hot air, e.g. wing slat, engine intake and cowling
  o chemical, e.g. aircraft wing, flying controls and windscreen ground anti-icing.

● Function and operation of reactive de-icing systems, including:
  o pneumatic, e.g. inflate/deflate wing leading edge de-icer boots
  o electromagnetic-impulse, e.g. wing, tail leading edge impulse ice removal
  o chemical, e.g. weeping wing and tail system, propeller slinger ring system.

**Fire detection and extinguishing systems and components**

● Fire detection:
  o fire-detection zones, including engines, auxiliry power unit (APU), jet pipes, cargo compartment, toilets
  o function and operation of fire/overheat detector systems, including:
    – unit-detector systems, e.g. thermal switch, thermocouple, inertia switches, crash switches, detector circuit, alarm circuit, test circuit
    – continuous loop detector systems, e.g. Fenwal and Kidde resistance-sensing systems, dual-loop systems, pneumatic sensing systems, fire-detection control unit
  o function and operation of smoke-, carbon monoxide- and flame-detection systems, including:
    – smoke and carbon monoxide detectors, e.g. light refraction, ionisation, electronic, chemical colour change
    – flame detectors, e.g. optical infrared, optical ultraviolet
  o nature of flight-deck and cabin-fire warnings, including location indicators, red lights, claxons, overheat indicators.
• Fire extinguishing:
  o classes of fire, including Class A fires involving ordinary combustible materials, Class B fires involving flammable liquids, Class C fires involving energised electrical equipment, Class D fires involving combustible metals
  o use of on-board system and hand-held extinguishing agents, including carbon dioxide, halon 1211, halon 1301, hydrofluorocarbon HFC-125, water
  o layout and function of on-board fire extinguishing system components, including extinguisher bottles, discharge valves, cartridges, extinguisher plumbing, two-way check valves, bottle pressure and thermal discharge indicators
  o pilot and automatic operation of extinguishing actuation system.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

| Assessment and grading criteria | To achieve a pass grade the evidence must show that the learner is able to: | To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to: | To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to: |
|---------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **P1** inspect one hydraulic-power, landing-gear and flight-control system safely | **M1** analyse, using the practical findings from the safe inspection and research, the operation of hydraulic power, landing gear and flight control systems and their components, identifying their contribution to safe flight | **D1** justify, using the findings from safe inspection and research, the function and operation of hydraulic-power, landing-gear and flight-control systems and their components, assessing the contribution made by each to safe flight |
| **P2** explain, using the practical findings and research, the operation of hydraulic-power, landing-gear and flight-control systems and their components, identifying their contribution to safe flight | **M2** analyse the function and operation of cabin environmental control, oxygen, safety and emergency equipment systems and components, identifying their contribution to the protection of passengers and crew | **D2** evaluate, using language that is technically correct and of a high standard, the function and operation of cabin environmental control, oxygen, safety and emergency equipment systems and components, assessing the contribution to the protection of passengers and crew |
| **P3** explain the function and operation of cabin environmental control systems and components, identifying their contribution to the protection of passengers and crew | | |
| **P4** explain the function and operation of oxygen, cabin safety and emergency equipment systems and components, identifying their contribution to the protection of passengers and crew | | |
## Assessment and grading criteria

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<td><strong>P5</strong> explain the function and operation of airframe fuel systems and components, identifying their contribution to safe flight</td>
<td><strong>M4</strong> analyse the function and operation of airframe fuel, icing and fire-protection systems and components, identifying their contribution to safe flight.</td>
<td><strong>D3</strong> evaluate the function and operation of airframe fuel, icing and fire-protection systems and components, assessing the contribution to safe flight.</td>
</tr>
<tr>
<td><strong>P6</strong> explain the function and operation of airframe icing and fire-protection systems and components, identifying their contribution to safe flight.</td>
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</table>
Essential guidance for tutors

Assessment

For P1, learners will, in order to understand their function and operation, safely inspect one hydraulic-power, one landing-gear and one flight-control system.

For example, the inspection of a hydraulic supply system will be used to determine the identity, layout and function of the system and its power source(s), oil-storage components, fluid plumbing, control valves and feeds to the hydraulic services.

For P2, learners will use the findings of inspections and further research to explain the function and operation of hydraulic-power, landing-gear and flight-control systems and their components, identifying their contribution to safe flight. The explanation will include the operation of the system under normal and emergency conditions. For example, explaining how the aircraft’s landing gear may be lowered using an alternative supply, an accumulator or blown-down facility in an emergency-supply situation, identifying the contribution made to safe flight by the landing-gear system under these conditions.

Overall, the evidence will be logically structured but may be basic in parts and contain minor technical inaccuracies, for example it may be missing some constructional detail on the wheel and brake assembly when explaining the layout of the alighting gear system.

For P3 and P4, learners will explain the function and operation of pneumatic, air-conditioning and pressurisation, environmental control subsystems and components. For example, when examining the function and operation of the cabin air-conditioning system, learners will explain how the bled and ram air supplies are mixed and conditioned before entry into the cabin, and how the quality of cabin air is maintained. Learners will identify how the air-conditioning system contributes to the continuing safety of passengers and crew.

Learners will explain the function and operation of oxygen, safety and emergency equipment systems and components, under both normal and emergency conditions, and identify the contribution made by each system to the protection of passengers and crew. For example, when examining the operation of a ring main and a chemical oxygen supply to the cabin drop-down oxygen-mask units, the method of delivery of oxygen to the masks for both systems will be explained and the cabin emergency conditions needed to activate oxygen flow to the masks and the systems’ contribution to passenger and crew protection will be identified.

Overall, the evidence will be logically structured but may be basic in parts and contain minor technical inaccuracies, for example it may miss some construction detail when explaining the operation of the cabin air re-circulation system used to maintain the quality of cabin air.

For P5 and P6, learners will explain the function and operation of airframe fuel systems and components, identifying their contribution to safe flight. The explanation will include the operation of the fuel system and the function of fuel-system components for engine fuel-feed, fuel-jettison and refuel/defuel modes. For example, when explaining the operation of an aircraft fuel system in the fuel-jettison mode, the function in the system of the fuel-transfer and fuel-jettison valves will be explained and the contribution to safe flight of the fuel system and valves will be identified.
Learners will explain the function and operation of de-icing, anti-icing and fire-detection and extinguishing systems and their components, and will identify their contribution to safe flight. The explanation will include identification of de-icing chemicals, the function and operation of ice-detection, anti-icing and de-icing systems, together with the nature of fire-extinguishing agents and the function and operation of fire-detection and extinguishing systems and their components. For example, when examining the function and operation of a chemical weeping wing, de-icing system, the nature of the chemical de-icer and the layout and function of the components in the system must be explained, and the contribution to safe flight of the system and its components must be identified.

Overall, the evidence will be logically structured but may be basic in parts and contain minor technical inaccuracies, such as failing to identify all of the functions for a particular type of anti-icing or de-icing system.

For M1, learners will draw on findings in their analysis from the safe inspection of one hydraulic-power supply, one landing-gear and one flight-control system and on further research of these systems. For example, the analysis of an aircraft's hydraulic-power-supply system should consider the types of power source, control valves, fluid plumbing and multiplex supply feeds it provides to the aircraft hydraulic services.

Learners will identify the contribution to safe flight of hydraulic-supply, landing-gear and flying-control systems. For example, by considering the normal and emergency operation of the landing gear, they will identify how the hydraulic systems contribute to the safe operation of the landing gear during the taxi, take-off, cruise and landing phases of flight.

Overall, the evidence should be logically structured, technically accurate and easy to understand. In particular, analysis will cover the function and operation of the systems and their components accurately under normal and emergency conditions.

For M2, learners will analyse the function and operation of pneumatic-, air-conditioning and pressurisation, environmental control subsystems and components. For example, when examining the function and operation of the cabin-pressurisation system and components, the actions of the cabin-pressure controller and discharge valves under normal and emergency conditions will be analysed and the contribution to the continuing safety of passengers and crew of these component actions will be identified.

Learners will analyse the function and operation of oxygen, safety and emergency equipment systems and components, under both normal and emergency conditions and identify the contribution made by each system to the protection of passengers and crew. For example, when examining the operation of a ring main and a chemical oxygen supply to the cabin drop-down oxygen-mask units, the emergency cabin conditions that lead to activating the oxygen supply, as well as the method and system components used to deliver the oxygen to the masks, will, in both cases, need to be analysed and their contribution to crew and passenger safety identified.

Overall, the evidence should be logically structured, technically accurate and easy to understand. In particular, analysis will cover accurately the function and operation, of aircraft fixed and walk-round oxygen systems and components, as well as the function of cabin safety and emergency equipment.
For M3 and M4, learners will analyse the function and operation of airframe fuel systems and components, identifying their contribution to safe flight. The analysis will include the operation of the fuel system and its components for engine fuel-feed, fuel-jettison and refuel/defuel modes. For example, when examining the operation of an aircraft fuel system, in the refuelling/defuelling mode, the operation of refuel-valve and fuel-tank isolation valves will be analysed and the contribution of the system and valves to the aircraft and to ground safety will be identified.

Learners will analyse the function and operation of de-icing, anti-icing and fire-detection and extinguishing systems and their components, and identify their contribution to safe flight. The analysis will include the function and operation of ice-detection, anti-icing and de-icing systems and components, fire-extinguishing agents, and fire-detection, warning and extinguishing systems. For example, when examining the function and operation of a hot-air, pre-emptive, anti-icing system, the operation of the ice-detector sensor and its control of the blown hot-air system will be analysed, and the contribution of the detector and its associated control and warning system to safe flight, will be identified.

Overall, the evidence should be logically structured, technically accurate and easy to understand. In particular, the analysis will cover accurately fuel types and additives, fire types and extinguishing agents, as well as the function and operation of fuel-, anti-icing, de-icing, fire-detection and extinguishing systems and components.

For D1, learners will provide a justification based on the findings from the safe inspection of one hydraulic-power supply, one landing-gear and one flight-control system, and will also be based on further research on these systems. Learners could do this, for example, by considering alternative hydraulic supply sources and component type and layout required for all the essential hydraulic services under emergency conditions.

Learners will assess the contribution to safe flight of hydraulic-supply, landing-gear and flight-control systems. For example, when considering the operation of a landing-gear system, the interaction between pilot throttle settings, airspeed, weight switches, landing-gear extension/retraction, and the maintenance of safe flight will be assessed.

Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer. The evidence will be logically structured, use correct engineering terms and will be of a high standard of written language. In particular, the well-reasoned justification will cover concisely and consistently the function and operation of the systems and their components under normal and emergency conditions.

For D2, learners will evaluate the function and operation of pneumatic, air-conditioning and pressurisation, environmental control subsystems and components. For example, the operation of the systems and function of system components responsible for the safe passage and conditioning of the air, from the engine bled and ram air supplies into the pressurised cabin, under normal and emergency conditions, will be evaluated and the contribution of each to the protection of passengers and crew will be assessed.

Learners will evaluate the function and operation of oxygen, safety and emergency equipment systems and components, under both normal and emergency conditions and the assessment of the contribution made by each system to the protection of passengers and crew. For example, when examining the operation of a ring main oxygen supply system and a chemically-generated oxygen supply system to the cabin drop-down oxygen-mask units, the emergency cabin conditions that lead to
activating the oxygen supply, the method and system components used to deliver the oxygen to the masks and the relative merits of the two different oxygen-supply systems and components, will be evaluated and their contribution to crew and passenger safety will be assessed.

Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer. The evidence will be logically structured, use correct engineering terms and will be of a high standard of written language.

For D3, learners will evaluate the function and operation of airframe fuel systems and components, assessing their contribution to safe flight. The evaluation will include an analysis of fuel types and additives and the operation of fuel-system components during fuel-feed, jettison, refuelling and defuelling modes. For example, when examining an engine fuel system in the fuel-feed mode, the operation of the fuel-flow pumps and transfer valves, will be evaluated and the contribution to safe flight of the fuel system and these components will be assessed.

Learners will evaluate the function and operation of de-icing, anti-icing and fire-detection and extinguishing systems and their components and assess their contribution to safe flight. The evaluation will include the function and operation of ice detection, anti-icing/de-icing systems and components, fire-, heat- and smoke detectors, flight-deck and cabin-fire warnings, fire-extinguishing systems and the nature and use of extinguishing agents. For example, when examining a fire-detection and extinguishing system, the operation of the particular type of fire-detector and flight-deck warning system, together with the manual and automatic actuation of the extinguisher bottles, must be evaluated and the contribution of the system and components, assessed.

Overall, the evidence presented will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured and use correct engineering terms.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, D1</td>
<td>Aircraft-Hydraulic Power, Landing-Gear and Flight-Control Systems</td>
<td>An activity requiring learners to inspect and research aircraft-hydraulic power, landing-gear and flight-control systems.</td>
<td>A report based on inspections of systems and research, covering the function and operation of aircraft-hydraulic power, landing-gear and flight-control systems as well as components and their contribution to safe flight.</td>
</tr>
<tr>
<td>P3, P4, M2, D2</td>
<td>Cabin Environmental Control and Emergency Systems</td>
<td>An activity requiring learners to research the operation of cabin environmental control and emergency systems.</td>
<td>A report covering the operation of cabin environmental control and protection systems, as well as components and their contribution to the protection of passengers and crew.</td>
</tr>
<tr>
<td>P5, P6, M3, D3</td>
<td>Airframe Fuel, Icing and Fire Protection Systems</td>
<td>An activity requiring learners to research airframe fuel, icing and fire protection systems.</td>
<td>A report covering the operation of airframe fuel, ice and fire protection systems, as well as components and their contribution to safe flight.</td>
</tr>
</tbody>
</table>
Essential resources

For this unit, learners must have access to the following specialist physical resources:

- a functional aircraft hydraulic supply system, either on-aircraft or in the form of a test rig
- an aircraft hydraulic landing gear complete with wheel and brake assembly, doors and fairings and with access to hydraulic retraction/extension system and system components
- a complete functional mechanical or hydraulic flying control system, with access to identify and view the layout of system components
- sight of a cabin-conditioning and pressurisation environmental control system and components
- sight of an airframe de-icing/anti-icing system and components
- sight of a fire-detection and suppression system and components
- sight of cabin or cockpit safety and emergency equipment, as detailed in the content section.

Please note that some or all of the required physical resources identified above may not necessarily be directly available at the centre delivering the unit but may be available at the premises of a partner or related organisation. Ideally, the resources will be available on a training aircraft.
Unit 14: Aircraft Electrical and Instrument Systems

Level: 3  
Unit type: Optional  
Assessment type: Internal  
Guided learning: 60

Unit introduction

Electrical and instrument systems are fundamental to the safe operation of aircraft. Aircraft need to be safe with reduced environmental impact and with the ability to operate more efficiently. This leads engineers to find new ways of increasing electrical power generation, which is required for increasingly complex modern aircraft operation.

In this unit, learners will apply practical skills and understanding to the construction and operating principles of a range of modern electrical components and instruments, as well as to their associated systems. They will look at the technology and characteristics of electrical generators and learn how power is managed and distributed to where it is needed, helping to ensure the safe operation of the aircraft. They will learn about the function and operation of electrical motors and actuators, loading, control and warning systems and their contribution to safe flight. Finally, through practical work, learners will explore the construction and operation of aircraft air data and gyroscopic flight instruments.

This unit will help to prepare learners for an aircraft engineering apprenticeship and for employment in an aircraft technician role. The unit will also help them to progress to higher education.

Learning outcomes

On completion of this unit a learner should:

1. Examine how electrical power generation and distribution systems support the safe operation of aircraft
2. Examine how electrical actuation, loading, control and warning systems contribute to maintaining safe flight
3. Explore how air data and gyroscopic instruments and systems contribute to maintaining safe flight.
Unit content

1 Examine how electrical power generation and distribution systems support the safe operation of aircraft

Aircraft electrical power generation
- Operation and construction of direct current (DC) generators, including:
  - type, including shunt wound, series wound, compound wound, voltage regulation
  - protection and control, including reverse current, over/under voltage, position sensing and temperature control
  - load sharing and paralleling.
- Operation and construction of alternating current (AC) single-phase and multiphase brushed and brushless generators, including:
  - constant frequency (CF), variable frequency (VF), variable speed constant frequency (VSCF), three-phase star and delta connections, voltage regulation, generator paralleling
  - protection control, including over/under voltage, excitation and frequency, differential current and correct phase rotation.

Aircraft electrical power distribution
- Function, system operation and layout of primary and secondary power sources, including single and multiple DC and AC generator systems, integrated drive generators (IDG), auxiliary power unit (APU), ground power.
- Aircraft electrical services provided by the essential, non-essential and vital services bus-bar feeds.
- Function, types and system operation of emergency power source components, including:
  - main and emergency batteries, e.g. nickel/cadmium, lead acid, sealed
  - Ram Air Turbine (RAT) emergency electrical power generator, standby generators.
- Function and operation of power conversion and protection components including DC to AC inverters, AC to DC transformer rectifier units (TRU), circuit breakers and relays.

2 Examine how electrical actuation, loading, control and warning systems contribute to maintaining safe flight

Electric motors and actuators
- Operation, including construction, principles and application of the following types of DC and AC motors, including:
  - DC brush types, e.g. shunt wound, series wound, compound wound, need for heat dissipation, speed and torque characteristics and control methods
  - DC brushless types, e.g. electronically controlled switching of rotor coils, rotor position sensor, speed, torque and operating temperature characteristics, comparisons with brushed motors
  - AC single phase, e.g. split phase, capacitor start, shaded pole, need for field windings, types of starter circuits, currents on start-up, speed torque characteristics
AC three phase, e.g. squirrel cage, synchronous, wound rotor, reduction of power losses, speed torque characteristics, comparisons with single phase motors

miscellaneous motors types, operating principles and aircraft use, e.g. servo motors, stepper motors, and linear motors.

Aircraft electrical actuators:

motor-driven actuator types, construction and operation, including gearing mechanisms, rotational and linear movement parameters and working cycle and power requirements

aircraft actuator applications, including the operation of rotary and linear shut-off valves, temperature control valves, flap drives, motor-driven pumps, engine starters, air-conditioning fans and blowers.

Electrical loading systems

Function and operation of airframe loading systems, including:

external lighting, e.g. navigation lights, high intensity strobe lights, landing and taxiing lights, inspection lights, emergency exit lights

internal lighting, e.g. cockpit and flight deck, passenger information, bay lighting for cargo areas, equipment lighting, emergency/evacuation lighting and indicators

electrical anti-icing and de-icing, e.g. intake cowls, windscreen, propellers, spinners, probe and drain heating.

Electrical control and warning systems

Function and operation of electrical fire control and warning systems, including:

electrical fire detection and warning, engine and jet pipe overheat thermal detectors, switches and fire wire

electrical control of fire suppressants and extinguishing systems

fire warning lights and audible alerting devices.

Cockpit or cabin, centralised and configuration warning panels and indicators, including information displayed, types of warning given.

Stall warning systems, including stall detectors, cabin warning indicators, stick shakers.

Engine health monitoring and indicating systems, e.g. exhaust gas, manifold, engine turbine temperatures and pressures, rotational engine speed, fuel flow, torque, thrust, oil pressure, vibration measurement.

Cabin environmental control, e.g. temperature and pressure warnings.

Aircraft landing gear, e.g. indications, use of weight-on switches.
3 Explore how air data and gyroscopic instruments and systems contribute to maintaining safe flight

Air data instruments and systems

- Operation, including principles and construction of air data instruments, including:
  - altimeters, ambient static port, aneroid capsule pressure sensor, gearing and altitude setting knob
  - vertical speed indicator (VSI), operation during level, diving and climbing flight
  - airspeed indicator (ASI) pitot-static data inputs, instrument, pressure, compressibility and density errors
  - Machmeter, use of capsules for altitude corrected airspeed.

- Function and operation of pitot-static systems, including pressure heads, static vents, pipelines, pitot-static leak checks.

- Air data computer (ADC), including functions, block schematic, total temperature, static and pitot pressure inputs, outputs, e.g. true air temperature, auto-throttle, VSI, autopilot, cabin pressure computer.

Gyroscopic principles and instruments

- Gyroscopic principles, including gyroscopic rigidity and precession, laws of gyrodynamics, Sperry’s rule, gyroscopic wander, electrically and pneumatically powered gyroscope spin.

- Function, construction and operation of gyroscopic instruments, including:
  - artificial horizon, gyroscopic tumbling, directional and rate gyroscopes and degrees of freedom, direction indicators
  - turn and slip indicator and turn coordinators, gyroscopic action in banked turn, differences between indicators and coordinators
  - laser gyroscopes, principles of interferometry (superimposing waves), benefits of strap-down (no moving parts) technology over electromechanical counterparts.

- Flight instrument panel layout, information and indications, including:
  - basic six grouping, e.g. ASI, altimeter, direction indicator, gyro-horizon, VSI, turn and bank indicator
  - basic T grouping, e.g. combined airspeed indicator, attitude direction indicator, horizontal situation indicator, altimeter, radio magnetic indicator and VSI.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td><strong>P1</strong> explain how DC and AC electrical power is produced and controlled, for safe flight</td>
</tr>
<tr>
<td><strong>P2</strong> explain how DC and AC electrical power is distributed and converted within an aircraft under normal and emergency conditions for safe flight</td>
</tr>
<tr>
<td><strong>P3</strong> explain the operation, application and contribution to safe flight of aircraft electric motors, actuators and loading, control and warning systems</td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P4</strong> assemble one gyroscopic and two air data instruments safely, after investigating their operation.</td>
<td><strong>M3</strong> analyse, using practical findings from safe assembly of instruments and research, the operation of one gyroscopic and two air data instruments to help ensure safe flight.</td>
<td><strong>D3</strong> justify, using the practical findings from safe assembly and inspection and research, the operation, function and layout of air data and gyroscopic instruments and their associated pitot-static and flight instrument display systems, assessing their contribution to safe flight.</td>
</tr>
<tr>
<td><strong>P5</strong> explain, using the practical findings and research, the operation of one gyroscopic and two air data instruments to help ensure safe flight.</td>
<td><strong>M4</strong> analyse, using the findings from safe inspection of instruments and research, the function and layout of one pitot-static system and one flight instrument display, identifying their contribution to safe flight.</td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> inspect one pitot-static system and one flight instrument display safely.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> explain, using the practical inspection findings and research, the function and layout one pitot-static system and one flight instrument display, identifying their contribution to safe flight.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will explain how DC and AC electrical power is produced and controlled for safe flight. The explanation will include the operating principles and control of the electrical output from both DC and AC aircraft generators. For example, learners will explain clearly the constructional arrangement, function and operation of the fixed windings, armature and commutator in a DC machine, and explain how the quality of the output voltage and current is controlled within limits, using regulators.

For P2, learners will explain how DC and AC electrical power is distributed and converted in an aircraft under normal and emergency conditions for safe flight. The explanation should detail the distribution and nature of electrical power from the supplies, including the batteries, to the non-essential, essential and vital services and bus-bars under normal and emergency operating conditions. Only the function and electrical inputs and outputs from the conversion components such as TRU and inverters, need be included.

Overall, the evidence will be structured logically but may be basic in parts and contain minor technical inaccuracies, for example omitting or incorrectly identifying the thermostatic switch or damper windings when explaining the operation of a complex brushless AC aircraft generator.

For P3, learners will explain the operation, application and contribution to safe flight of aircraft electric motors, actuators, and loading, control and warning systems. The explanation will include details on the construction, operating principles and characteristics of the types of DC motor identified in the content, together with at least one example of a single-phase and a multiphase AC motor. The explanation will also cover the operation and application of the linear and rotary actuators that use these DC and AC motors as their power source.

Learners will explain the function and operation of aircraft loading, control and warning systems, identifying their contribution to safe flight. For example, when considering an engine health and monitoring system, they will explain the nature of the warning indications on the instrument panel such as engine temperatures, oil pressure and vibration measurement and identify the effect they have on maintaining safe flight.

Overall, the evidence will be structured logically but may be basic in parts and contain minor technical inaccuracies, for example omitting a particular indication of engine health such as torque when explaining the nature of the warning indications given by an engine health monitoring system.

For P4, learners will assemble one gyroscopic and two air data instruments safely to explore their operation. For example, learners will dismantle an unlabelled instrument such as an ASI, VSI or Machmeter, with the screen masked or removed. They will investigate the arrangement of the capsules and gearing and input/output ports to determine the function and operation of the instrument. They will sketch or take photographs of the internal components and gearing to aid their explanation. After completing the exploration the instrument should be safely assembled and return to the state in which it was presented.

For P5, learners will explain, using the practical findings and research, the operation of one gyroscopic and two air data instruments to help ensure safe flight. For example, they will research air data and gyroscopic instruments to confirm the correct identification and function of the instrument being investigated and provide
a detailed explanation of its operation. As a minimum, the flight instrument display
being explored should contain an airspeed indicator, altimeter, gyro-horizon,
direction indicator, vertical speed indicator and a turn and bank indicator or any
combination of these instruments for analysis.

For P7, learners will inspect one pitot-static system and one flight instrument
display safely, and use findings to explain their function and layout, identifying their
contribution to safe flight, for P8. For example, when exploring a pitot static
system, they will determine the layout of the pitot-static feeds, vents and
associated piping to the pitot-static instruments and establish their function.
Learners will also identify the contribution to safe flight of each of the instruments
in the system. If the pitot-static system being explored uses an air data computer
(ADC), only the inputs to and outputs from this device need to be determined.

Overall, the evidence will be structured logically but may be basic in parts and
contain minor technical inaccuracies, such as missing some detail when explaining
the layout of the gearing between the capsules and display of a pitot-static
instrument.

For M1, learners will analyse how DC and AC electrical power is produced and
controlled under normal and emergency conditions for safe flight. For example,
when analysing the production of electrical power from a self-excited DC generator,
the relationship between the type, i.e. shunt, series and compound wound
generators and their operating characteristics should be taken into account when
considering their selection for aircraft electrical power production.

Learners will analyse how electrical power is distributed and converted under
normal and emergency conditions for safe flight. For example, learners will analyse
the distribution and conversion of the 28 volt DC supply from the main generator to
the non-essential and essential services DC bus bar under normal operation and the
continued supply of DC power to the essential services bus bar, in an emergency
when the main DC generator is faulty or off-line.

Overall, the evidence should be logically structured, technically accurate and easy
to understand. The depth of evidence will include details of the ways in which
aircraft DC and AC power is controlled and converted at key component level, for
example detailing the function and operating principles of an inverter and a
Transformer Rectifier Unit TRU in the electrical supply system.

For M2, learners will analyse the operation, indications and application of aircraft
electric motors, actuators, loading, control and warning systems, identifying the
contribution made by each to safe flight. It will include an analysis of the operation
and application of different types of DC and AC electric motors and actuators,
lighting, anti-icing and de-icing systems, as well as the operation and indications
given for fire, stall, engine health, cabin environment and landing gear, control and
warning systems.

Learners will identify the contribution made by electrical actuators and loading,
control and warning systems to safe flight. For example, in the event of an engine
bay overheat warning from the fire detection system, the types and form of the
indications and warnings given to the pilot and the subsequent actions that are
taken automatically by the system or manually by the pilot will be analysed, and
their effect on safe flight identified.

Overall, the evidence should be logically structured, technically accurate and easy
to understand. The depth of evidence will include details on the function and
operation of all the different types of DC and AC electric motors and actuators, and
loading, control and warning systems laid out in the content. This will be in addition
to evidence that identifies the contribution made by each function and operation to
safe flight.
For M3 and M4, learners will assemble one gyroscopic and two air data instruments safely and use the findings from the practical exploration together with those from research to analyse the operation and identify their contribution to safe flight. For example, when exploring a gyro-instrument, learners will be able to recognise the difference between a directional gyroscope and a rate gyroscope and will be able to determine the function and operation of the instrument.

Learners will inspect one pitot-static system and one flight instrument display safely and use findings to analyse their function and layout and to identify their contribution to safe flight.

Overall, the evidence should be logically structured, technically accurate and easy to understand. For example, when exploring the operation of a flight instrument the evidence will include accurately-labelled drawings and/or photographs of its construction, internal components and display, to accompany the written analysis.

For D1, learners will evaluate the operation, including principles and characteristics, construction and application of DC and AC generators. Learners will establish how electrical power is produced by these generators and how the quality of their output is controlled to ensure a regulated electrical supply for safe flight under normal and emergency operating conditions. For example, when evaluating the modern brushless AC generator, the use and operation of the constant speed drive unit and voltage regulator will be included. Learners will show how these components control the quality of the electrical output to the AC services bus-bar and how paralleling (load-sharing) of multi-generator aircraft electrical systems maintains a regulated AC supply in the event of a single generator failure.

Learners will evaluate how the distribution, control and protection of electrical power is directed and prioritised to the electrical services under normal and emergency conditions, for both single- and multi-engine aircraft. For example, in the event of complete failure of the main generators on a multi-engine aircraft, learners will show how the electrical supply from the emergency generator and/or battery system is directed, converted and supplied to both the DC and AC vital services.

Overall, the evidence presented will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured, use correct engineering terms and have a high standard of written language.

In particular, the balanced evaluation will concisely and consistently cover the production of DC and AC aircraft electrical power and the control, regulation, distribution and prioritisation of electrical power under normal and emergency situations.

For D2, learners will evaluate the function, operation, construction and application of electric motors and actuators and analyse how they contribute to safe flight. When evaluating the application and contribution to safe flight of aircraft electric motor-driven actuators, their characteristics and use in engine starter systems, valve operation, air-conditioning fans and blowers and flying controls will be analysed.

Learners will evaluate the function, operation and contribution to safe flight of aircraft loading systems, including lighting, anti-icing and de-icing systems. For example, when evaluating anti-icing and de-icing systems the contribution to safe flight of air-intake heater mats and pitot-static probe heaters will be analysed.

Learners will evaluate the function, operation and indications given for aircraft control and warning systems. The evaluation should include an analysis of the contribution to safe flight of fire suppression and protection, stall warning, engine health monitoring, cabin environmental control and landing gear systems.
Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and use correct engineering terms. In particular, the balanced evaluation will also include an analysis of the contribution made by the motors, actuators and loading, control and warning systems in maintaining safe flight. For example, when considering electrical fire detection and warnings, the exact nature of the detector and circuitry will be analysed to identify the type and location of the overheat causing the warning.

For D3, learners will provide a reasoned justification of the construction, function, operation and layout of aircraft, air data and gyroscopic instruments and their associated pitot-static and flight instrument display systems, assessing their contribution to safe flight.

The justification will draw on findings from the safe dismantling, inspection and assembly of one gyroscopic and two air data instruments and further research on air data and gyroscopic instruments. For example, when inspecting a Machmeter, the function of the altitude capsule, as well as the airspeed capsule will be analysed and related to the measurement of airflow at varying altitude. A justification will be given for the use of this instrument on high-speed aircraft, rather than using a simple airspeed indicator. Learners will explore one aircraft pitot-static system and one cabin flight display panel safely and use the findings to justify their function, layout and indications to the pilot and, to assess their contribution to safe flight.

The justification will include both electric and pneumatically powered air-data instruments and the use of strap-down technology for gyroscopic instruments. For example, when considering strap-down technology such as a laser gyroscope, its advantages and disadvantages need to be assessed and a case made justifying its use over its mechanical counterparts and assessing its contribution to safe flight.

Overall, the evidence presented will be easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and use correct engineering terms.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, D1</td>
<td>Aircraft Electrical Power Generation and Distribution</td>
<td>An activity requiring learners to research aircraft generators and power distribution components and systems.</td>
<td>A report covering the operation, including construction, principles, control and protection of aircraft generators and power distribution components and systems.</td>
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<tr>
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<tr>
<td>P3, M2, D2</td>
<td>Electrical Motors and Actuators, Loading, Control and Warning Systems</td>
<td>An activity requiring learners to research electrical motors, actuators, loading, control and warning systems.</td>
<td>A report covering the function, layout, operation and aircraft application of electrical motors, actuators, loading, control and warning systems.</td>
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<tr>
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</tr>
<tr>
<td>P4, P5, P6, P7,</td>
<td>Air Data Instruments and Systems and Gyroscopic Principles and Instruments</td>
<td>Learners carry out practical tasks to explore air data instruments and systems and gyroscopic instruments.</td>
<td>A series of practical tasks to safely explore the function, construction and operating principles of air data instruments and systems and gyroscopic instruments. Evidence will include observation records/witness statements, annotated photographs and/or drawings and procedural details.</td>
</tr>
</tbody>
</table>
Essential resources

For this unit, learners must have access to the following specialist physical resources:

- a range of aircraft electric motors, actuators and actuator driven components, on or off aircraft, capable of being dismantled inspected and assembled
- an air data or pitot-static system and an aircraft instrument display panel complete with a series of flight instruments; these may be on-aircraft or in the form of a mock-up
- sight of electrical generators (AC or DC) to allow learners to view the hardware in order to enhance theory
- a training aircraft to view conventional electrical loading, protection and warning systems.

Access to the above resources, in particular a training aircraft or realistic mock-ups, may be on-site or off-site in conjunction with appropriate training or an industrial partner.
Unit 15: Aircraft First Line Maintenance Operations

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Military, general aviation and civil airline organisations operate aircraft in a variety of roles. For such aircraft operations organisations need suitably qualified aircraft maintenance technicians to ensure the continued serviceability of their aircraft, in an operating environment.

In this unit, learners will examine the all-important safety measures that are foremost in all aspects of aircraft maintenance operations, as well as understand the mandatory procedures to be followed for the operations themselves. They will then consider the administrative procedures and quality processes that underpin the function, role, frequency and documentation needed for the maintenance operations. The final part of the unit requires learners to put into practice what they have learned and carry out a number of practical first-line maintenance operations. They will reflect on the processes undertaken, and on their own personal performance, so they can make improvements next time.

This unit will help prepare learners for an aircraft engineering apprenticeship, as well as more specifically assisting them in gaining employment in an aircraft maintenance technician role. Alternatively, they could choose to continue their studies in higher education.

Learning outcomes

On completion of this unit a learner should:

1. Examine aircraft safe maintenance operations in a first-line engineering environment
2. Examine the planning, quality processes and administrative procedures associated with aircraft first-line maintenance operations
3. Carry out aircraft first-line maintenance operations that safely restore aircraft to a serviceable condition
Unit content

1 Examine aircraft safe maintenance operations in a first-line engineering environment

Safety procedures for aircraft first-line maintenance operations

Safety procedures, or other relevant international equivalents, and actions to be followed, including:

- compliance with the Electricity at Work Regulations (EWR) 1989 and amendments
- awareness of local aircraft electrical safety hazards and procedures for earthing and bonding, radio transmission and connection/disconnection of aircraft ground power
- care and safe handling of pressurised gases, air, oxygen and nitrogen in accordance with the Dangerous Substances and Explosive Atmospheres Regulations (DSAER) 2002 and amendments
- Control of Substances Hazardous to Health Regulations (COSHH) 2002 and amendments, including Personal Protective Equipment (PEE) at Work Regulations 2002 and amendments, aircraft fuel, engine and hydraulic oils, de-icing fluids, liquid oxygen (LOX)
- procedures, hazards and precautions when working at height (Work at Height Regulations 2005) and working in confined spaces, e.g. aircraft cockpit, engine intakes, and equipment bays
- compliance with local procedures for the operation of ground use fire extinguishers, chocking, blanking, and securing aircraft, anti-deterioration checks.

Types of aircraft first-line maintenance operations

- General maintenance operations, including:
  - aircraft movements, towing and marshalling
  - use and connection of, e.g. engine start equipment, passenger services equipment, radio microphones
  - fitment/removal of control locks, blanks and bungs
  - storage and inhibiting of aircraft, engines and major components
  - use, fitment and removal of highway staging, ladder, platforms
  - hoisting and lifting
  - operation of, e.g. air stairs, fuselage doors, cargo bay doors, cockpit canopies.

- Specialist maintenance operations, including:
  - walk round inspections for security of attachment of hatches, access doors, panels and fasteners, leaks, tyre condition, general damage
  - abnormal occurrence checks and procedures for, e.g. lightning strike, tyre burst, heavy landing, bird strike, flight through turbulence
  - fluid replenishment, e.g. air, oxygen, nitrogen, LOX, engine oils, hydraulic oils, component lubrication
  - refuelling and defuelling
- ground de-icing/anti-icing, cold weather actions
- connection/disconnection of aircraft ground power, e.g. electrical, hydraulic, pneumatic
- jacking and trestling, wheel change
- avionic – cabin, instrument, navigation or landing light bulb replacement, battery condition checks, pitot-static sense and leak checks.

2 Examine the planning, quality processes and administrative procedures associated with aircraft first-line maintenance operations

Maintenance planning and quality processes

- Civil or military maintenance planning, including:
  - approved maintenance programmes and schedules
  - servicing cycles, e.g. check, equalised, opportunity
  - additional maintenance requirements; e.g. minor and major modifications, special technical instructions (STI), servicing instructions (SI), airworthiness directives (AD) and notices.

- Civil or military quality processes, including:
  - functions and roles of quality departments – quality control and assurance processes, inspection processes
  - function and roles of checks; e.g:
    - first, second, third and fourth line check system
    - A, C, D, ramp and transit system
    - scheduled and unscheduled checks
    - authorisations, duplicate inspections, independent checks
  - control of life limited components and equipment, e.g. hard-time, on-condition, condition monitoring.

Administrative procedures for aircraft maintenance

Civil or military administration, including:

- content and purpose of documentation:
  - maintenance manuals, repair manuals
  - records and recording documents including historical record cards, serial and part numbers, logbooks
  - certification; e.g. certificate of release to service (CRS), Ministry of Defence (MOD) form 700

- stores systems:
  - layout, procedures
  - parts and equipment tracking and record keeping
  - quarantine stores, bonded stores
  - parts classification; e.g. aircraft general spares (AGS), A, B, C stores, consumables, life-limited items
  - issue of parts and equipment, hard copy and computer based parts manuals.
3 Carry out aircraft first-line maintenance operations that safely restore aircraft to a serviceable condition

Preparation for aircraft first-line maintenance operations

Preparation activities, including:

- consult the appropriate documentation and/or supervisor to determine the nature and type of maintenance operation required
- ensure appropriate entries are and have been made in the aircraft log or job card
- comply with relevant operational procedures, job card instructions and safety procedures
- obtain all tools and equipment necessary for safe completion of the maintenance operation.

Aircraft general first-line maintenance operations

General maintenance operations, e.g.:

- assist with aircraft moving, towing or marshalling operations
- connect and disconnect engine start equipment or passenger services equipment
- fit and remove control locks, blanks and bungs
- assist with securing and preparing aircraft for inclement weather
- assist with safe handling or inhibiting and storage of aircraft engine or airframe or avionic components and equipment
- fit and remove highway staging, ladders or platforms
- assist with hoisting, winching or lifting operations
- operate air stairs, fuselage doors, cargo bay doors or aircraft canopies.

Aircraft specialist first-line maintenance operations

Prepare, administer and carry out specialist first line maintenance operations, e.g.:

- walk round checks
- assist with abnormal occurrence checks
- lubricate aircraft components, equipment and linkages
- drain and replenish fluid systems
- assist with aircraft refuelling and/or defuelling
- assist with aircraft ground de-icing
- assist with aircraft anti-deterioration checks and tests
- connect and disconnect aircraft electrical ground power
- connect and disconnect aircraft hydraulic or pneumatic power rigs
- assist with jacking and trestling aircraft
- change an aircraft wheel or brake unit
- replace a cabin instrument, navigation or landing light filament
- check battery charging and condition
- perform sense and leak checks on a pitot static system
- remove and fit an avionic line replaceable unit (LRU).
4 Review aircraft first-line maintenance operations and reflect on personal performance

Lessons learned from aircraft first-line maintenance operations

Scope of the lessons learned should cover:

- health and safety skills, to include – familiarity and compliance with laid down health and safety procedures and hazard prevention actions when ground handling aircraft and equipment and when carrying out aircraft maintenance operations in a first line area or hangar

- aircraft first line maintenance skills, e.g. interpreting maintenance information sources and procedures, selection care and control of tools and equipment for each particular maintenance operation, post maintenance checks and tests and the raising and completion of appropriate maintenance documentation.

Personal performance while carrying out aircraft first-line maintenance operations

Understand the relevant behaviours when working in an aircraft maintenance environment, including:

- taking initiative and responsibility for own actions when applying knowledge and practical skills to aircraft maintenance operations that are safe, efficient and independent; e.g. awareness and use of appropriate maintenance manuals and documentation and the selection and use of appropriate tools and equipment for the particular maintenance operation

- communication and literacy skills to interpret and comply with aircraft safety and maintenance procedures and to ensure the correct and accurate entries are completed in the relevant documentation

- problem solving issues as they occur; e.g. overcoming the logistical and safety problems of aircraft access and use of servicing equipment such as oxygen or engine oil replenishment trolleys, in a first line operational environment.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
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<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td><strong>P1</strong> explain what safety procedures and actions are required to complete general and specialist maintenance operations</td>
</tr>
<tr>
<td><strong>P2</strong> explain the functions and roles of planning and quality processes on aircraft maintenance operations</td>
</tr>
<tr>
<td><strong>P3</strong> explain the functions and roles of the administrative procedures used to support aircraft maintenance operations</td>
</tr>
<tr>
<td><strong>P4</strong> complete three general and three specialist aircraft maintenance operations safely and using the correct processes, including appropriate inspections, checks and tests</td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
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<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
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<tbody>
<tr>
<td><strong>P5</strong> explain how health and safety procedures and aircraft maintenance operations were applied effectively in an aircraft maintenance environment.</td>
<td><strong>M4</strong> recommend improvements to the aircraft maintenance operations and to the relevant behaviours applied.</td>
<td><strong>D3</strong> demonstrate consistently good technical understanding and analysis of the aircraft maintenance operations, including the application of relevant behaviours to a professional standard.</td>
</tr>
<tr>
<td><strong>P6</strong> explain how relevant behaviours were applied effectively to aircraft maintenance operations.</td>
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</table>
Essential guidance for tutors

Assessment

For P1, learners will explain the safety and operational procedures that must be followed to complete different types of specialist and general first-line maintenance operations. For example, the safety zones, when approaching, working on or marshalling aircraft with running engines are required to reduce or eliminate the hazards associated with engine intake ingestion or hot exhaust emissions.

They should also explain, for P2 and P3, the functions and roles of planning and quality processes and administrative procedures. For example, explaining the need for planned inspections and the release of work cards from the planning department, to ensure that the maintenance operations are carried out during aircraft down time and are accompanied by the appropriate documentation to ensure their safe delivery.

Overall, the explanations will be logically structured, although basic in parts and they may have one or two omissions. For example, when considering the type of maintenance activity related to gaining access to and exiting the aircraft, they may omit the procedures to be followed when carrying out ground handling operations on cargo doors, having previously covered only the main aircrew passenger doors and emergency doors.

For P4, learners will complete safely three general and three specialist first-line maintenance operations. Evidence of the safe completion of these maintenance operations may be obtained by those witnessing or testifying to learners’ understanding and compliance with relevant safety procedures and precautions, as well as with the identification and use of the correct maintenance tools, equipment, operational procedures and documentation. Learners will need to complete all appropriate entries in the relevant documentation, including appropriate inspections, checks and tests. For example, that all maintenance activities have been carried out and signed for on the job cards, including the need to clear entries for any inspections, checks or tests directly related to the specific maintenance operation being carried out and the need to call for over signatures, as required.

Overall, any supporting evidence may be limited, for example there may be little evidence of preparation activities and the inspection documentation, although complete, may not be detailed.

For P5, learners will detail in their evidence (such as a technical report of around 500 words in length) the lessons learned during each of the three general and three specialist maintenance operations. The evidence will explain the actions taken to ensure their own personal safety and the safety of others in aircraft operational and maintenance areas, such as the use of personal protective clothing and pre-use checks on equipment. For example, the wearing of a face visor, protective gloves, apron and footwear, the positioning of a fire appliance and carrying out pre-use checks on a liquid oxygen (LOX) trolley prior to recharging the aircraft LOX system.

For P6, the evidence will further detail relevant behaviours that were applied when working in an aircraft maintenance operational environment, for example time management to ensure completion of work to deadlines and good husbandry to ensure cleanliness and a maintenance environment that is free of foreign object debris (FOD).
Overall, the evidence will be well organised and laid out clearly so that a third party would be able to understand how learners’ skills have been applied. Efforts will be made to use some technical language where appropriate, although there may be some inaccuracies with spelling and grammar. Also, some parts of the evidence may be considered in greater depth than others.

For M1 and M2, learners will assess the most relevant safety and operational procedures, and the actions required to undertake first-line maintenance operations safely. They will consider the consequences of not taking the appropriate action. Learners will assess the most relevant planning, quality processes and administrative procedures when undertaking aircraft first-line maintenance operations and how the efficiency of the operation is affected. For example, the management of stores and tool control reduce the hazards associated with lost or mislaid spares or tools. This reduces the potential harm to objects, including the aircraft, and improves the efficiency of the maintenance operations being undertaken as spares and tools are more likely to be available when required.

Overall, the evidence will be logically structured, technically accurate and easy to understand.

For M3, learners will provide evidence of the safety, accuracy and efficiency of the three general and three specialist aircraft first-line maintenance operations being undertaken. The evidence may be gauged by the standard of the documentation presented in the evidence. Also by those witnessing or testifying to the logical approach adopted by learners with respect to information gathering, the handling and completion of documentation, as well as the order of the maintenance operations and sequence and nature of the inspections, checks and tests.

Overall, the evidence presented for the maintenance operations undertaken should be logically presented, technically accurate and easily understood.

For M4, learners will make recommendations as to where improvements could be made. For example, the management of health and safety to decrease the risk of harm to self and others, for example posting warning notices and/or cordonning-off the area before commencement of a lifting operation that takes place at height, posing a drop hazard to those working or walking below. The logic in the order of the steps and checks taken throughout the maintenance operation, for example, ensuring that a complete walk round inspection is carried out before making entries in the documentation for any faults found. Thus ensuring that all appropriate entries are made at the same time, rather than piecemeal, which will result in more efficient maintenance actions being taken. There will be the application of relevant behaviours to ensure that time goals are met and maintenance operations are completed in a more efficient manner.

Overall, the evidence will be logically structured, technically accurate and easy to understand.

For D1, learners will evaluate how the combined effect of safety procedures, planning, quality processes and administrative procedures impact on the efficient and safe delivery of first-line maintenance operations. For example, they will evaluate how planned servicing cycles and quality procedures improve the efficiency and safe delivery of inspections of lifted components by clearly identifying the frequency and type of checks these components require, during a first-line turn round, before flight or after flight maintenance operation. The evaluation will also include how the effects of hazards during maintenance operations can be minimised and the consequences that could result. For example, not refuelling the aircraft at the same time as replenishing oxygen during a turn round inspection reduces the risk of an explosion.
Overall, the evidence presented will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured, use correct engineering terms and will be of a high standard of written language, for example grammatically correct.

For D2, learners will refine, during the process, three general and three specialist aircraft maintenance operations to ensure aircraft serviceability and integrity, by undertaking thorough and comprehensive pre and post maintenance inspections, checks and tests. For example, before completing a wheel change, resulting from a worn or damaged tyre initial inspection of the undercarriage bay, the brakes and the under wing area will be carried out to ascertain if there is any foreign object debris damage, hydraulic fluid leakage or other physical damage, that has occurred. Also, for example, post maintenance checks will be carried out on wheel brake operation as well as on the wheel for correct fit, security of attachment and function.

Overall, the evidence will be presented clearly in a way that would be understood by a third party, who may or may not be an engineer. There will be a comprehensive record of the safety and operational procedures followed, together with accurately and correctly completed documentation for each of the maintenance operations completed.

For D3, learners will, in their analysis, demonstrate consistently good technical understanding, including the application of relevant behaviours. For example, learners will take responsibility for their own actions and safety, before, during and after the connection of electrical ground power to an aircraft. Ensuring that all relevant documentation checks to ascertain the maintenance state of the aircraft have been carried out, ensuring that aircraft bonding and earthing measures are taken, other technicians working in or around the aircraft are informed and all switches, circuit breakers and other isolation devices are correctly and safely positioned before, during and after electrical ground power is connected and disconnected.

Overall, the evidence presented will be easy to read and understand by a third party who may or may not be an engineer. For example, learners should consistently demonstrate a good technical understanding of aircraft first-line maintenance operations that includes correct technical engineering terms and information about improvements.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, M1, M2, D1</td>
<td>Planning, Administrative and Safety Procedures and Quality Processes Involved in First-line Maintenance</td>
<td>An activity requiring learners to research the function, use and compliance with the necessary procedures and processes.</td>
<td>A report focusing on operational maintenance procedures and the function, use and compliance with planning, administrative and safety procedures and quality processes necessary to restore the aircraft to a serviceable condition in a first-line engineering environment.</td>
</tr>
<tr>
<td>P4, M3, D2</td>
<td>Preparing For and Carrying Out Aircraft General and Specialist First-line Maintenance Operations</td>
<td>Learners carry out general and specialist maintenance operations, including the necessary preparations.</td>
<td>A series of practical tasks to complete aircraft maintenance operations safely. Evidence will include: a record of the procedures followed, observation records and correctly completed servicing documents, with witness signatures against each completed task.</td>
</tr>
</tbody>
</table>
### Essential resources

Please note that the required physical resources may not necessarily be directly available at the centre delivering this unit, but could be made available on the premises of a partner organisation.

For this unit, learners must have access to:

- appropriate information sources, including relevant maintenance manuals, operational procedures and work recording documentation, such as job cards, maintenance logs and servicing schedules; EASA, CAA or equivalent military publications, first-line maintenance safety procedures, notices and safety drills

- appropriate tools, and ground servicing equipment suitable for the general and specialist maintenance operations identified in the content

- a minimum of one training aircraft and its associated ground support equipment, with the capacity for first line maintenance operations; for example: ground handling operations, moving, marshalling, jacking, connection of ground power, component lubrication, fluid system replenishment; fluid, mechanical and electrical systems/equipment maintenance including functional checks and tests.
Unit 16: Properties and Applications of Engineering Materials

Level: 3  
Unit type: Optional  
Assessment type: Internal  
Guided learning: 60

Unit introduction

In-depth knowledge of the structure and behaviour of engineering materials is vital for anyone who is expected to select or specify them for applications in the engineering industry. This unit will give an understanding of the structures, classifications and properties of materials used in engineering and will enable learners to select materials for different applications.

The unit is appropriate for learners engaged in manufacturing and mechanical engineering, particularly where materials are sourced in the form of stock to be used in a production process. The unit covers a range of materials, some of which learners may not be familiar with initially.

This unit will enable learners to identify and describe the structures of metals, polymers, ceramics and composites and classify them according to their properties. Learners will describe the effects of processing on the behaviour of given materials. Smart materials whose properties can be altered in a controlled fashion through external changes – such as temperature and electric and magnetic fields – are also covered.

Learners will apply their understanding of the physical and mechanical properties of materials, design requirements, cost and availability to specify materials for given applications.

All materials have limits beyond which they will fail to meet the demands placed on them. The common modes of failure will be both demonstrated and explained to enable learners to recognise where an informed choice can make the difference between the success or failure of a product.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Know the structure and classification of engineering materials
2. Understand material properties and the effects of processing on the structure and behaviour of engineering materials
3. Be able to use information sources to select materials for engineering uses
4. Understand about the modes of failure of engineering materials.
Unit content

1 Know the structure of and classification of engineering materials

Atomic structure: element; atom, e.g. nucleus, electron; compound; molecule; mixture; bonding mechanisms, e.g. covalent, ionic, metallic

Structure of metals: lattice structure; grain structure; crystals; crystal growth; alloying e.g. interstitial, substitutional; phase equilibrium diagrams, e.g. eutectic, solid solution, combination; intermetallic compounds

Structure of polymeric materials: monomer; polymer; polymer chains, e.g. linear, branched, cross-linked; crystallinity; glass transition temperature

Structure of ceramics: amorphous; crystalline; bonded

Structure of composites: particulate; fibrous; laminated

Structure of smart materials: crystalline; amorphous; metallic

Classification of metals: ferrous, e.g. plain carbon steel, cast iron (grey, white, malleable, wrought iron), stainless and heat-resisting steels (austenitic, martensitic, ferritic); non-ferrous, e.g. aluminium, copper, gold, lead, silver, titanium, zinc; non-ferrous alloys, e.g. aluminium-copper heat treatable – wrought and cast, non-heat-treatable – wrought and cast, copper-zinc (brass), copper-tin (brass), nickel-titanium alloy

Classification of non-metals (synthetic): thermoplastic polymeric materials, e.g. acrylic, polytetrafluoroethylene (PTFE), polythene, polyvinyl chloride (PVC), nylon, polystyrene; thermostetting polymeric materials, e.g. phenol-formaldehyde, melamine-formaldehyde, urea-formaldehyde; elastomers; ceramics e.g. glass, porcelain, cemented carbides; composites, e.g. laminated, fibre reinforced (carbon fibre, glass reinforced plastic (GRP)), concrete, particle reinforced, sintered; smart materials, e.g. electro-rheostatic (ER) fluids, magneto-rheostatic (MR) fluids, piezoelectric crystals

Classification of non-metals (natural): e.g. wood, rubber, diamond

2 Understand material properties and the effects of processing on the structure and behaviour of engineering materials

Mechanical properties: strength (tensile, shear, compressive); hardness; toughness; ductility; malleability; elasticity; brittleness

Physical properties: density; melting temperature

Thermal properties: expansivity; conductivity

Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity

Effects of processing metals: recrystallisation temperature; grain structure, e.g. hot working, cold working, grain growth; alloying elements in steel, e.g. manganese, phosphorous, silicon, sulphur, chromium, nickel

Effects of processing thermoplastic polymers: polymer processing temperature; process parameters, e.g. mould temperature, injection pressure, injection speed, mould clamping force, mould open and closed time

Effects of processing thermostetting polymers: process parameters, e.g. moulding pressure and time, mould temperature, curing

Effects of processing ceramics: e.g. water content of clay, sintering pressing force, firing temperature
Effects of processing composites: fibres, e.g. alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cerments

Effects of post-production use: smart materials, e.g. impact (piezoelectric), electric field (electro-rheostatic), magnetic field (magneto-rheostatic), temperature (shape memory alloys), colour change (temperature or viscosity)

3 Be able to use information sources to select materials for engineering uses

Information sources: relevant standard specifications, e.g. British Standards (BS), European Standards (EN), International Standards (ISO); material manufacturers’ and stockholders’ information, e.g. data sheets, catalogues, websites, DVDs

Design criteria: properties, e.g. mechanical, physical, thermal, electrical and magnetic; surface finish; durability, e.g. corrosion resistance, solvent resistance, impact resistance, wear resistance

Cost criteria: initial cost, e.g. raw material, processing, environmental impact, energy requirements; processing, e.g. forming, machining, casting, joining (thermal, adhesive, mechanical); quantity; mode of delivery e.g. bulk, just-in-time (JIT); recycling

Availability criteria: standard forms, e.g. sheet and plate, bar-stock, pipe and tube, sectional, extrusions, ingots, castings, forgings, pressings, granular, powder, liquid

4 Understand about the modes of failure of engineering materials

Principles of ductile and brittle fracture: effects of gradual and impact loading, e.g. tensile, compressive, shear; effects of grain size; transition temperature; appearance of fracture surfaces

Principles of fatigue: cyclic loading; effects of stress concentrations, e.g. internal, external; effects of surface finish; appearance of fracture surfaces

Principles of creep: primary; secondary; tertiary; effects of temperature; strain versus time curve; creep limit; effect of grain size; effect of variations in the applied stress

Tests: destructive, e.g. tensile, hardness, impact, ductility, fatigue, creep; non-destructive, e.g. dye penetrant, ultrasonic, radiographic (x-ray, gamma ray), magnetic powder, visual

Degradation processes: on metals, e.g. oxidation, erosion, stress corrosion; on polymers, e.g. solvent attack, radiation and ageing; on ceramics, e.g. thermal shock, sustained high temperature
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
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<tbody>
<tr>
<td><strong>P1</strong> describe the structure (including the atomic structure) associated with a given metal, polymer, ceramic, composite and smart material</td>
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<tr>
<td><strong>P2</strong> classify given engineering materials as either metals or non-metals according to their properties</td>
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</tr>
<tr>
<td><strong>P3</strong> explain mechanical, physical, thermal and electrical and magnetic properties and state one practical application of each property in an engineering context</td>
<td></td>
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</tr>
<tr>
<td><strong>P4</strong> explain the effects on the properties and behaviour of processing metals, polymers, ceramics and composites and of post-production use of smart materials</td>
<td><strong>M1</strong> explain how the properties and structure of different given engineering materials affect their behaviour in given engineering applications</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P1, P2, P3, P4, M1: Learning outcomes related to material science and engineering.
### Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P5</strong> use information sources to select a different material for two given applications, using the criteria considered in the selection process</td>
<td><strong>M2</strong> explain the criteria considered in the selection process</td>
<td><strong>D1</strong> justify selection of an engineering material for one given application</td>
</tr>
<tr>
<td><strong>P6</strong> explain the principles of the modes of failure known as ductile/brittle fracture, fatigue and creep</td>
<td><strong>M3</strong> explain how two given degradation processes affect the behaviour of engineering materials</td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> perform and record the results of one destructive and one non-destructive test method using one metal and one non-metallic material</td>
<td><strong>M4</strong> explain how one destructive and one non-destructive test procedure produces useful results.</td>
<td><strong>D2</strong> evaluate the results of one test procedure.</td>
</tr>
<tr>
<td><strong>P8</strong> explain a different process of degradation associated with each of metals, polymers and ceramics.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Centres have the option to decide on the number of tasks and the order in which the criteria are covered.

The evidence to satisfy the pass criteria P1, P2 and P3 could be achieved by means of a written assignment following a combination of tutor-led practical and theory sessions and individual research. P2 would require the range of materials given to include at least one ferrous, one non-ferrous, one non-ferrous alloy, one thermoplastic polymer, one thermosetting polymer, an elastomer, one ceramic, one composite, one smart material and one natural material.

Achievement of P4 and M1 could involve learners in both practical and theoretical tasks in which they relate the effects of processing on the properties of materials with real engineering applications. For smart materials, they need to consider the effects on the properties of the materials’ use after production. Examples here may be related to their change in properties from the effects of external stimuli. For example, when a force is applied to a piezoelectric material it produces an electric charge which can be used to trigger a car’s airbag in the event of an accident. In many applications the behaviour is reversible, for example a colour change in response to a change in temperature or a variation in the viscosity of a liquid in response to the application of an electric or magnetic field. To satisfy P5, it is likely that learners would apply the knowledge and understanding gained in meeting criteria P1 to P4. Written responses would satisfy these criteria.

P7 could be met using a combination of practical and research activities involving tutor-led demonstrations of available laboratory tests. Learners could then carry out a series of tests and produce a written record of the test results. A witness statement could confirm the learner’s involvement. Depending on available resources, it may be best to carry out the destructive test on the non-metallic material and the non-destructive test on the metallic material. This would allow a wider choice of tests for the latter. To achieve P6 and P8, learners could be given the opportunity to research modes of failure and degradation processes reflected in local conditions, for example a marine environment, or, for employed apprentices, failure and degradation pertinent to their companies’ products.

To achieve the merit grade M1, learners will need to explain how the structure and properties of given materials will affect their behaviour in use. This evidence would be best demonstrated by a written task related to the activities carried out to meet P1, P2 and P3. For M2, learners should consider design, cost and availability criteria in their explanation. To satisfy M3, learners could produce a written explanation of the test procedures followed in P7 and the usefulness of the results. In producing evidence for some of this criterion it may be appropriate to include the responses to oral questions. However, centres should ensure that such questions and the responses are recorded for verification and also that they are not the sole source of evidence. M4 could be achieved through an extension of the task given for P8.

The processes used in the explanation could be selected to meet local conditions or industrial applications.
To achieve distinction criterion D1, learners need to justify their selection of one of the materials used to satisfy P5, giving reasons why other materials considered for the application were not selected. To satisfy D2, learners are expected to complete a written task to evaluate the results of one of the tests used to meet P7 and M4. The evidence would depend on the test used but it could include the mathematical results of a tensile test, the values of a hardness test or detailed information gained from a non-destructive test.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3</td>
<td>Structure and Classification of Engineering Materials</td>
<td>Questions relating to the structure and classification of the range of engineering materials.</td>
<td>A written report containing reasoned answers to the set questions.</td>
</tr>
<tr>
<td>P5, M2, D1</td>
<td>Selection of Engineering Materials</td>
<td>Selection of engineering materials for given applications.</td>
<td>A written report listing selection criteria, information sources and justification for selected materials.</td>
</tr>
<tr>
<td>P6, P8, M3</td>
<td>Failure and Degradation of Engineering Materials</td>
<td>Questions relating to the range of failure modes and degradation processes in engineering materials.</td>
<td>A written report containing reasoned answers to the set questions.</td>
</tr>
<tr>
<td>P7, M4, D2</td>
<td>Testing Engineering Materials</td>
<td>Carry out and report the results of destructive and non-destructive tests on engineering materials.</td>
<td>A written report containing an explanation of test procedure and evaluation of test results.</td>
</tr>
</tbody>
</table>
Essential resources

Centres will need a selection of exemplar materials and components for viewing, tactile inspection and discussion. Degraded and failed component specimens will also be of value. Centres will also require access to equipment to conduct at least one destructive and one non-destructive test and related materials as specified in the unit content.

Indicative reading for learners

Textbooks


Higgins R – Materials for Engineers and Technicians (Routledge, 2014) ISBN 9781138778757


Unit 17: Further Mechanical Principles of Engineering Systems

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

All machines and mechanisms consist of interconnected parts working together to produce a desired output. Engineers involved in the design, testing and servicing of mechanical systems need to have a firm grasp of the underpinning principles in order to appreciate the choice of components, the forces acting on them and the way that they relate to each other.

The study of stationary structures and their components is often referred to as 'statics'. The first two learning outcomes cover the mechanical principles that underpin the design of framed structures, simply supported beams and structural components. The aim is to give learners the means to evaluate the integrity and safety of engineering structures and to lay the foundation for structural analysis at a higher level.

A great many engineering systems are designed to transmit motion and power. These include machine tools, motor vehicles, aircraft and a range of domestic appliances. The study of the motion in mechanical systems is known as 'kinematics' and the study of the forces at work and the power they transmit is known as 'dynamics'. Learning outcomes 3 and 4 aim to extend learners' knowledge of the mechanical principles associated with these studies. Learning outcome 3 aims to provide a basic knowledge of rotational motion and the effects of centripetal force in simple rotating systems. In learning outcome 4, learners are introduced to simple machines used as lifting devices. An understanding of the mechanical principles involved in the operation of these devices and mechanisms will provide a foundation for the analysis of more complex power transmission systems at a higher level of study.

Note that the use of 'e.g.' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'e.g.' needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Be able to determine the forces acting in pin-jointed framed structures and simply supported beams
2. Be able to determine the stress in structural members and joints
3. Be able to determine the characteristics of rotating systems
4. Be able to determine the operating characteristics of simple lifting machines.
Unit content

1 Be able to determine the forces acting in pin-jointed framed structures and simply supported beams

*Pin-jointed framed structures:* solution e.g. graphical (such as use of Bow’s notation, space and force diagram), analytical (such as resolution of joints, method of sections, resolution of forces in perpendicular directions \( F_x = F \cos \theta, F_y = F \sin \theta \)), vector addition of forces, application of conditions for static equilibrium \( (\Sigma F_x = 0, \Sigma F_y = 0, \Sigma M = 0) \)

*Forces:* active forces, e.g. concentrated loads; uniformly distributed loads (UDL); reactive forces, e.g. support reactions, primary tensile and compressive force in structural members

*Simply supported beams:* distribution of shear force and bending moment for a loaded beam, e.g. concentrated loads, UDL; types of beam arrangement, e.g. beam without overhang, beam with overhang and point of contraflexure

2 Be able to determine the stress in structural members and joints

*Single and double shear joints:* fastenings, e.g. bolted or riveted joints in single and double shear; joint parameters, e.g. rivet or bolt diameter, number of rivets or bolts, shear load, expressions for shear stress in joints subjected to single and double shear, factor of safety

*Structural members:* members, e.g. plain struts and ties, series and parallel compound bars made from two different materials; loading, e.g. expressions for direct stress and strain, thermal stress, factor of safety

3 Be able to determine the characteristics of rotating systems

*Rotating systems with uniform angular acceleration:* systems, e.g. simple (such as rotating rim, flywheel, motor armature, pump or turbine rotor), complex (such as systems where combined linear and angular acceleration is present, hoist and vehicle on an inclined track); kinetic parameters, e.g. angular displacement, angular velocity, angular acceleration, equations for uniform angular motion \( \omega_f = \omega_i + at, \theta = \omega_i t + \frac{1}{2} a t^2, \omega_f^2 = \omega_i^2 + 2a \theta, \theta = \frac{1}{2} (\omega_i + \omega_f) t \);

dynamic parameters, e.g. radius of gyration, moment of inertia \( (I = mk^2) \), inertia torque \( (T = I \alpha) \), friction torque, application of D’Alembert’s principle, mechanical work \( (W = T \theta) \), power (average power \( = \frac{W}{t} \), instantaneous power \( = T \omega) \),

rotational kinetic energy \( (KE = \frac{1}{2} I \omega^2) \), application of principle of conservation of energy

*Rotating systems with uniform centripetal acceleration:* systems, e.g. simple (such as concentrated mass rotating in a horizontal or vertical plane, vehicle on a hump-backed bridge, aircraft performing a loop), complex (such as centrifugal clutch, vehicle on a curved track); kinetic parameters, e.g. expressions for centripetal acceleration \( (a = \omega^2 r, a = \frac{v^2}{r}) \); dynamic parameters,

ee.g. expressions for centripetal force \( (F_c = m \omega^2 r, F_c = \frac{mv^2}{r}) \)
4 Be able to determine the operating characteristics of simple lifting machines

Parameters of lifting machines: kinetic parameters, e.g. input motion, output motion, velocity or movement ratio, overhauling; dynamic parameters, e.g. input effort, load raised, mechanical advantage or force ratio, law of a machine, efficiency, limiting efficiency

Lifting machines: lifting machines, e.g. simple (such as inclined plane, screw jack, pulley blocks, wheel and axle, simple gear train winch), differential (such as differential wheel and axle, Weston differential pulley block, compound gear train winch)
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td><strong>P1</strong> illustrate graphically the magnitude and nature of the support reactions and primary forces acting in the members of a framed structure with at least four pin-jointed members</td>
<td><strong>M1</strong> analyse the magnitude and nature of the support reactions and primary forces acting in the members of a framed structure with at least four pin-jointed members</td>
<td><strong>D1</strong> determine the values of distribution of shear force and bending moment and locate a point of contraflexure for a simply supported beam with overhang carrying at least two concentrated loads and a continuous uniformly distributed load</td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong> determine the values of distribution of shear force and bending moment for a simply supported beam without overhang carrying at least three concentrated loads</td>
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<td></td>
</tr>
<tr>
<td><strong>P3</strong> determine the values of required parameters for a single shear lap joint and a double shear butt joint for given service conditions</td>
<td><strong>M2</strong> determine the values of induced stresses and dimensional changes that occur in the materials of a series connected compound bar and a parallel connected compound bar when subjected to direct loading</td>
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</tr>
<tr>
<td><strong>P4</strong> determine the induced direct stress, dimensional change and factor of safety values in operation for a rigidly held plain structural member when subjected to a combination of direct and thermal loading</td>
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<tr>
<td>P5 determine the outcomes of applied torque, work done and power dissipated in a uniformly accelerated simple rotating system to overcome the effects of inertia and friction</td>
<td>M3 determine the performance value of a complex rotating system due to the effects of centripetal acceleration</td>
<td>D2 determine the applied torque, work done and power dissipated outcomes in a uniformly accelerated complex rotating system in which both linear and rotational motion is present, to overcome the effects of inertia, friction and gravity.</td>
</tr>
<tr>
<td>P6 determine the centripetal acceleration and centripetal force values in a simple rotating system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P7 determine the outcomes of kinetic and dynamic parameters of operation of two different simple lifting machines from given data.</td>
<td>M4 evaluate the kinetic and dynamic parameters of operation of a differential lifting machine.</td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Ideally, assessment of this unit will be achieved through application of the mechanical principles covered to the relevant engineering settings. This could be achieved through integration with other engineering principles units, practical work that provides learners with opportunities to produce individual evidence for assessment against the criteria, and individual project/assignment tasks. Whichever approach is taken, it is important to ensure that the criteria are achieved autonomously. Where centres consider a test/examination necessary to achieve authentic evidence, they need to ensure that the test items are set in a way to enable the criteria to be met in full. Centres also need to consider how such an assessment will provide opportunities to meet the merit and distinction criteria, and how to provide learners with further learning and assessment should they initially fail to achieve in the test/examination.

If learners make an arithmetic error in the solution to a problem, it is for the centre to decide the significance of such an error, assess the work accordingly and provide suitable feedback. For example, if a learner has chosen the correct approach and manipulated the necessary formulae and data correctly, but has made and carried through a minor arithmetic error, then the final ‘inaccurate’ solution to the problem may be deemed to be good enough to meet the criterion. However, if the final solution to the problem is so obviously wrong that it should have prompted further checks for accuracy, then the solution could be deemed to be unacceptable and reassessment considered. The incorrect application of units and/or dimensions are a typical cause of such major errors, which can lead to relatively large scale errors of the magnitude $10^3$ or greater.

It is possible to assess the criteria P1, P2, M1 and D1 through an assignment requiring the graphical and analytical solution of a given pin-jointed framed structure and the analysis of given simply supported beams. The magnitude and nature of the framed structure support reactions and internal forces may be illustrated graphically (P1) and confirmed analytically (M1). Learners should make use of Bow’s notation in their analysis.

The simply supported beam for P2 should contain at least three concentrated loads and be supported at its free ends. The simply supported beam for D1 should overhang one of its supports and contain at least two concentrated loads and a continuous uniformly distributed load. Learners should be required to adopt an analytical approach to locate the point of contraflexure.

A second assignment could assess the criteria P3, P4 and M2. The first task might be to determine the parameters for a single shear lap joint and for a double shear butt joint (P3) for given service conditions. This might involve calculation of the rivet/bolt diameter required for a given load or the safe working load for a particular joint. The joints should contain at least three rivets/bolts (six in total for the butt joint).

A second task might be to calculate the direct stress induced in a rigidly fixed member due to direct loading and temperature change (P4). A further task could involve evaluation of the stresses and dimensional changes occurring in series and parallel connected compound bars (M2) when subjected to direct loading.
A third assignment could be used to assess the criteria P5, P6, M3 and D2. The first task might involve consideration of a simple rotating system, such as a flywheel, which is accelerated against the effects of inertia and friction (P5). A second task might involve consideration of a more complex system such as a hoist or a vehicle on an incline in which both linear and angular motion is present (M3).

The third task might be to determine the centripetal acceleration and centripetal force present in a simple rotating system (P6). A final task would require learners to determine effects of centripetal acceleration and force in a more complex rotating system (D2). This might involve determining the speed of engagement and power transmitted by a centrifugal clutch. Alternatively, learners could evaluate the active and reactive forces on a vehicle travelling round a curved level track, maximum safe speed and the banking angle required for no tendency to side-slip at a given speed. The term performance in the criterion is therefore relevant to the particular rotating system given/used.

A final assignment containing two tasks could be used to achieve the P7 and M4 criteria. The first task would involve determination of velocity ratio, mechanical advantage and efficiency of two simple lifting machines for given input conditions (P7). Exemplar machines are ranged in the unit content.

In a second task, the M4 merit criterion could be achieved by means of a practical or simulated investigation of a differential lifting device. This should involve the determination of velocity ratio and the gathering of a sufficiently wide range of load and effort values for analysis of the machine performance. Graphs of load versus effort and load versus efficiency can then be plotted from the manipulated and tabulated test data. The law of the machine can be derived from the load versus effort graph and the theoretical value of the limiting efficiency obtained. An evaluation of this limiting value can then be made by comparison with that indicated on the load versus efficiency graph. An evaluation can also be made as to the likelihood of overhauling. Again, exemplar machines for this task are ranged in the unit content.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, P2, M1, D1</td>
<td>Forces and Moments in Static Systems</td>
<td>Analysis of pin-jointed framed structures and simply supported beams.</td>
<td>A written report containing required graphics and an appropriate introductory explanation to each step in the sequence of calculations and findings.</td>
</tr>
<tr>
<td>P3, P4, M2</td>
<td>Stress in Static System Components</td>
<td>Determination of parameters for riveted joints and determination of stress in plain and compound structural members.</td>
<td>A written report containing an appropriate introductory explanation to each step in the sequence of calculations and findings.</td>
</tr>
<tr>
<td>P5, P6, M3, D2</td>
<td>Dynamic Systems</td>
<td>Determination of dynamic system parameters and performance.</td>
<td>A written report containing an appropriate introductory explanation to each step in the sequence of calculations and findings.</td>
</tr>
<tr>
<td>P7, M4</td>
<td>Lifting Machines</td>
<td>Determination of the parameters and performance of simple lifting machines.</td>
<td>A written report containing an appropriate introductory explanation to each step in the sequence of calculations and findings.</td>
</tr>
</tbody>
</table>
Essential resources

Centres could provide access to laboratory facilities with a range of equipment for investigation and demonstration purposes wherever possible. In particular, flywheels or other rotor systems for the determination of moment of inertia and radius of gyration, turntable apparatus for the investigation of centripetal acceleration and force and a range of simple lifting machines.

Indicative reading for learners

Textbooks

Unit 18: Applications of Mechanical Systems in Engineering

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Mechanical engineering is a term that covers a wide range of activities. Mechanical systems are found in land, sea and air transport, power generation, manufacturing plant and domestic products. The design, manufacture and maintenance of such systems is the concern of engineers and technicians who must apply a blend of practical and theoretical knowledge to ensure that these systems work safely and efficiently.

Moving parts usually require some form of lubrication and learning outcome 1 examines lubricant types and lubrication systems. Pressurised systems often require seals and gaskets to contain the lubricants and other working fluids. Rotating parts require bearings and mechanical systems incorporate fixing devices to hold the various components in position. A range of seals, bearings and fastenings is examined in learning outcome 2.

A prime purpose of mechanical systems is to transmit motion and power. There are many ways in which this can be achieved and learning outcome 3 examines a range of power transmission systems and components. In learning outcome 4, learners are introduced to a range of plant equipment and systems. This includes an overview of hydraulic and pneumatic systems, steam plant, refrigeration and air conditioning plant and mechanical handling equipment.

The general aim of this unit is to broaden and extend learners’ practical knowledge and understanding of mechanical engineering systems and provide a foundation for continuing work in related units.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand the purposes and uses of lubricants and lubrication systems
2. Know about the uses and applications of a range of engineering components
3. Understand the operation and uses of mechanical power transmission systems
4. Understand the operation and uses of plant equipment and systems.
Unit content

1 Understand the purposes and uses of lubricants and lubrication systems

*Lubricant purposes and types:* purpose, e.g. reduction of frictional resistance, reduction of wear, heat dissipation, prevention of corrosion, prevention of contamination; types, e.g. mineral, vegetable and synthetic oils and greases, graphite, compressed gases, cutting fluids

*Lubrication systems and maintenance:* operation of lubrication systems, e.g. gravity feed, forced feed, splash lubrication, capillary action, grease cups and nipples, grease packing, compressed air/gas bearings; maintenance, e.g. replenishment and renewal of lubricants, safe storage and handling

*Applications:* e.g. automobile engine, automobile transmission, machine tool, pump, compressor

2 Know about the uses and applications of a range of engineering components

*Seals, packing and bearings:* seals, e.g. rotary lip seals, mechanical seals, piston rings; packing, e.g. packed glands, gaskets, shims; bearings, e.g. plain journal, thrust, ball, roller (such as parallel or tapered), needle

*Fastenings:* screwed fastenings, e.g. metric bolts, studs and set screws, self-tapping screws, locking devices; rivets, e.g. snap head, pan head and countersunk heads, bifurcated and pop rivets

*Applications:* e.g. automobile engine, automobile transmission, other automotive sub-system, machine tool, pump, compressor, other mechanical system involving rotation and fluid containment, component assembly, maintenance and replacement

3 Understand the operation and uses of mechanical power transmission systems

*Cams and linkage mechanisms:* cams and followers, e.g. radial plate cams, cylindrical cams, face cams, knife edge followers, flat plate followers, roller followers; linkage mechanisms, e.g. slider-crank and inversions, four-bar linkage and inversions, slotted link quick return motion, Whitworth quick return motion

*Belt, chain and gear drives:* belt drives, e.g. flat, V-section, synchronous, tensioning device; chain drives, e.g. roller (such as single, duplex, triplex), morse rocker-joint, tensioning devices; gear trains, e.g. gear types (such as spur, helical, herring bone, bevel, spiral bevel, hypoid), simple, compound, worm, combinations, epicyclic

*Transmission shafts, clutches and brakes:* transmission shafts and couplings, e.g. sections (such as solid, hollow), flanged couplings, splined couplings, angle couplings (such as Hooke universal, constant velocity); clutches, e.g. dog, flat plate, conical, centrifugal, fluid couplings; brakes, e.g. friction (such as internal expanding, external contracting), disc, dynamometers (such as friction, fluid, electromagnetic)
4 Understand the operation and uses of plant equipment and systems

*Actuation and handling systems*: pneumatic and hydraulic actuation systems, e.g. system layout for automated plant and process operations, system components; safety and maintenance; mechanical handling systems, e.g. belt conveyers, roller conveyers, workshop gantry cranes, workstation jib cranes

*Steam, refrigeration and air conditioning plant service systems*: steam power generation plant, e.g. system layout for power generation and process operations, system components, feed water treatment, safety and maintenance; refrigeration systems, e.g. system layout for vapour compression and absorption systems, refrigerants, system components, safety and maintenance; air conditioning systems, e.g. system layout for full summer and winter cycle air conditioning, system components, safety and maintenance
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
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<tr>
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<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td>P1 explain the purpose and application of three different types of lubricant</td>
</tr>
<tr>
<td>P2 explain the operation and maintenance of three different lubrication systems</td>
</tr>
<tr>
<td>P3 describe the operation of one seal, one type of packing and two different types of bearing, giving a typical application for each one</td>
</tr>
<tr>
<td>P4 describe two different types of screwed fastening and two different types of rivet giving a typical application for each one</td>
</tr>
<tr>
<td>P5 explain the operation of two different types of cam and follower and two different types of linkage mechanism</td>
</tr>
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<tr>
<td><strong>P6</strong> explain the arrangement and operation of two different kinds of belt drive, two different kinds of chain drive and two different kinds of gear train</td>
<td><strong>M2</strong> compare different types of mechanical power transmission systems and explain the benefits and limitations of each</td>
<td><strong>D2</strong> justify the use of a particular mechanical power transmission system in a given engineering application.</td>
</tr>
<tr>
<td><strong>P7</strong> explain the arrangement and operation of two different kinds of transmission shaft and coupling, two different kinds of clutch and two different kinds of brake</td>
<td><strong>M3</strong> compare and contrast the operation and use of pneumatic and hydraulic actuation systems.</td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> explain, with the aid of diagrams, the general layout and operation of a pneumatic actuation system, a hydraulic actuation system and a mechanical handling system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> explain, with the aid of diagrams, the general layout and operation of a steam power generation plant, a refrigeration system and an air conditioning system.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Criteria P1, P2, M1 and D1 could be achieved through an individual assignment. This should contain tasks to explain the purpose and application of three different types of lubricant (P1) and the operation and maintenance of three different lubrication systems (P2). M1 is an extension of P1 involving a comparison of the three lubricants in terms of their benefits and limitations. To achieve D1, learners should fully justify the use of a particular lubricant and lubrication system in a given engineering application. This might be the lubrication system of a vehicle engine or transmission, a machine tool, pump or compressor. Alternatively, a mechanical system required to operate in a hostile service environment such as extremes of temperature may be considered.

A second assignment could be used to assess P3 and P4. This would require learners to describe the operation and application of one type of seal, one type of packing and two different types of bearing (P3). Another task would need to cover two different types of screwed fastener and two different types of rivet (P4). The applications should be general, rather than product specific, to demonstrate an understanding of purpose. Diagrams and sketches could be used to complement the descriptions.

Criteria P5 and P6, which relate to learning outcome 3 on mechanical power transmission systems, could be achieved through a third assignment. This should require learners to explain methods of transmitting/converting motion from one form to another by means of two different types of cam and follower and two different linkage mechanisms. It will also need to include two different kinds of belt drive, two different kinds of chain drive and two different kinds of gear train.

As with the previous assessment, learners should be encouraged to illustrate the descriptions with diagrams and freehand sketches.

Criteria P7, M2 and D2 relate to learning outcome 3 and could be achieved through a fourth assignment. This should contain tasks requiring learners to explain the arrangement and operation of two different kinds of transmission shaft coupling, two different kinds of clutch and two different kinds of brake (P7). To achieve M2, learners could compare and contrast the operation of manually operated and automatic friction clutches and fluid couplings. The comparisons should be of a general nature, although they may be accompanied by typical applications to illustrate usage. To achieve D2, learners should fully justify the choice of bearings, seals, packing and fastenings in a given engineering system. This again might be a sub-system of a vehicle, a machine tool or any mechanical system where rotation and the containment of fluid is involved.

A final time-constrained assignment could be used to assess P8, P9 and M3. This should contain tasks requiring learners to explain, with the aid of diagrams, the general layout and operation of pneumatic and hydraulic actuation systems (P8), a steam generation plant, a refrigeration system and an air-conditioning system (P9).
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1 and D1</td>
<td>Applications of Lubricants and Lubrication Systems</td>
<td>Learners need to describe lubricants and the operation of lubrication systems to a new learner.</td>
<td>A series of three written tasks in which learners provide explanations of three lubricants and the operation of lubrication systems. They are also asked to justify the use of a lubricant for a given application.</td>
</tr>
<tr>
<td>P3 and P4</td>
<td>Applications of Engineering Components</td>
<td>Learners need to investigate different components in order to find the best to use for a particular application.</td>
<td>A series of three written tasks in which learners describe the application of seals, packing, bearings and fasteners</td>
</tr>
<tr>
<td>P5 and P6</td>
<td>Applications of Cams and Drives</td>
<td>Learners need to investigate mechanical power transmission systems.</td>
<td>Two written tasks in which learners explain the use of cams, linkage mechanisms and chains and drives.</td>
</tr>
<tr>
<td>P7, M2 and D2</td>
<td>Applications of Brakes and Clutches</td>
<td>Learners need to investigate transmission shafts, clutches and brakes.</td>
<td>Two written tasks in which learners explain the operation of shaft couplings, clutches and brakes, make comparisons and justify the use of one system.</td>
</tr>
</tbody>
</table>
### Criteria covered

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</thead>
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<tr>
<td>P8, P9 and M3</td>
<td>Plant Equipment and Systems</td>
<td>Learners have been asked to produce a report on some new plant equipment and systems that their company is interested in using.</td>
<td>A time-controlled task in which learners produce written explanations and accompanying diagrams of actuation systems and steam, refrigeration and air conditioning systems. They should also carry out a comparison of pneumatic and hydraulic systems.</td>
</tr>
</tbody>
</table>

### Essential resources

Centres should have access to a range of engineering components, demonstration equipment and engineering and motor vehicle workshops.

### Indicative reading for learners

**Textbooks**


Unit 19: Organisational Efficiency and Improvement

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

In this unit, learners will gain an understanding of continuous improvement in their sector and identify areas in production where lean working could be used to aid the company. They will learn about quality control methods used in industry and understand the key factors required to remain competitive in the market.

Learners will understand the importance of human resource management in terms of building successful teams and the effect this can have on recruitment and retention of employees.

Note that the use of e.g. in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an e.g. needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Understand production activities
2. Understand application of quality control and quality assurance
3. Understand organisational improvement techniques and competitiveness
4. Understand personal rights and responsibilities in an organisation.
Unit content

1 Understand production activities

Types of production: e.g. mass; flow; automated; batch; one-off

Considerations: market requirements; design of product; plant and equipment availability; plant and equipment layout; personnel; production control; quality control; cost

Methods and application of cellular and just-in-time (JIT) production: relation to modern production requirements; application of Push and Pull types of production to meet company and customer needs and expectations

Stages of production planning: scheduling, loading, dispatching (coordination of pre-production activities); requirements, e.g. engineering drawings, technical data, personnel, machinery/tools, components, materials, consumables

Process charts: e.g. flow charts/diagrams, Gantt charts; symbols used in process charts

2 Understand application of quality control and quality assurance

Quality control and assurance: meaning of 'quality control' and 'quality assurance'; fitness for purpose, e.g. meeting customer expectations; purchasing; production planning and procedures for quality assurance; manufacture (process control); final inspection and dispatch; Statistical Process Control (SPC), e.g. measuring quality/performance, document control as an integral part of quality assurance, records of the correct operation; types and the purpose of sampling, e.g. spot check, random sampling, process sampling, batch sampling; mean time between failures (MTBF) in the context of sample size and frequency

Inspection: checking every stage for deviation from design specification; adjustments that need to be made; stages of inspection, e.g. goods inward, during production (process control), final inspection; role of the inspector in checking compliance with quality standard and procedures; quarantine area to store defective work

BS EN ISO 9001: internationally recognised quality assurance standard; role of the quality manual and process/procedures manual; internal/external audits

Quality manager: relationship with other managers/departments in the company; considerations to be made when developing a quality plan, e.g. quality requirements (customer expectations), allocation of responsibilities (at all levels), the setting up of systems to measure quality and report progress, identification and calibration of quality equipment, ability to take corrective actions where necessary

Total quality management (TQM): main principles and goals; advantages of adopting TQM, e.g. competitiveness in the market, enabling growth and longevity, reducing stress, building teams, partnerships and cooperation
3 Understand organisational improvement techniques and competitiveness

*Business Improvement Techniques (BIT):* principles of lean manufacture, e.g. removal of waste of all kinds (time, motion, inventory, poor cost of quality etc.), stimulating productivity and quality; use of value-added processes, Kaizen as a philosophy that encompasses continuous improvement; just in time (stockless production or lean production), e.g. manufacturing to order not to stock; Kanban inventory control

*Productivity:* meaning of the term ‘production’; benefits to the company of increasing productivity; company, e.g. multinationals, nationals and regional, Small and Medium Enterprises (SMEs) and sole traders; managing the production process, e.g. layout of the production area, batch production, synchronisation, lead-time

*Continuous improvement:* meaning of ‘continuous improvement’; continuous improvement cycle (plan, do, check, and action); benefits gained; flexible working and multi-skilling; importance in the national and global marketplaces, e.g. multinationals, nationals, SMEs and sole traders

*Teamwork:* roles in a team, e.g. leaders, doers, thinkers, carers; balance in a team; what individuals bring to a team; team building; communication in the team

4 Understand personal rights and responsibilities in an organisation


*Development and progression opportunities:* company training programmes; apprenticeships; organisational training opportunities; promotion; transfer; higher education; professional qualifications

*Roles of representative bodies:* e.g. trade unions, professional bodies, employers’ organisations (EEF, the manufacturers’ organisation); industry training support

*Investors in People (IiP) national standard:* four key principles – commitment, planning, action and evaluation; how organisations acquire IiP status
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
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<tr>
<td><strong>P1</strong> explain the different types of production</td>
<td><strong>M1</strong> compare the advantages and disadvantages of different types of production</td>
<td><strong>D1</strong> justify the selection of a production type for a given process</td>
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<td><strong>P2</strong> describe the requirements that need to be considered when selecting a type of production</td>
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<td><strong>P3</strong> describe the different stages of production planning</td>
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<td><strong>P4</strong> explain how to apply typical process charts to production planning</td>
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<tr>
<td><strong>P5</strong> explain the meaning of the terms ‘quality control’ and ‘quality assurance’</td>
<td><strong>M2</strong> explain the importance of using a structured approach for quality control and quality assurance</td>
<td><strong>D2</strong> evaluate a quality management process and make suggestions for improvement</td>
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<tr>
<td><strong>P6</strong> describe the role and stages of inspection activities</td>
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<tr>
<td><strong>P7</strong> explain the application and content of the BS EN ISO 9000 series of standards</td>
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<td><strong>P8</strong> explain the role and responsibilities of the quality manager</td>
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<td><strong>P9</strong> describe the requirements of quality planning</td>
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<tr>
<td><strong>P10</strong> describe the principles of total quality management (TQM)</td>
<td><strong>M3</strong> explain the consequences for an organisation of not maintaining continuous improvement standards</td>
<td><strong>D3</strong> evaluate a production process and identify where improvements can be made to increase productivity and organisational competitiveness.</td>
</tr>
<tr>
<td><strong>P11</strong> explain the meaning of the terms Lean Manufacture, Kaizen, just-in-time and Kanban and their overall advantages</td>
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<tr>
<td><strong>P12</strong> explain the importance of improving organisational productivity</td>
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<tr>
<td><strong>P13</strong> describe the need for continuous improvement to ensure organisational competitiveness</td>
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<tr>
<td><strong>P14</strong> describe the key requirements for managing the production process</td>
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<tr>
<td><strong>P15</strong> explain the importance of teamwork and the individual’s contribution to effective teamwork</td>
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<td><strong>P16</strong> explain the key features of employment legislation in relation to personnel rights and responsibilities</td>
<td><strong>M4</strong> explain the effects of not adhering to employment legislation in relation to personal rights and responsibilities.</td>
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</tr>
<tr>
<td><strong>P17</strong> describe the personnel opportunities for development and progression that are available in the workplace</td>
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<tr>
<td><strong>P18</strong> describe the role of the representative bodies in the engineering sector that support personnel and organisations</td>
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</tr>
<tr>
<td><strong>P19</strong> explain the implications that ‘Investors in People’ has on an organisation and its personnel.</td>
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</table>
Essential guidance for tutors

Assessment

To achieve a pass grade, all the pass criteria must be met. Centres have the option to decide on the number of tasks and the order in which the criteria are covered.

The evidence to satisfy the pass criteria P1, P2, P3 and P4 could be achieved by means of a written task based upon a given product that needs to be manufactured. For P1, learners need to identify a range of production processes that could be used to manufacture a product and explain the underlying principles behind them. For P2, learners should identify the customer requirements for a given type of product and describe how these requirements will impact on the selection of a specific production method. For P3, learners would identify the key stages in production planning to produce their production plan for the given product. For P4, learners can add in the need and importance of process charts in the plan to identify key stages in the production. This can also allow learners to achieve M1 through a thorough analysis of the company. Alternatively a case study into quality management of a sample company could be used. At least two possible production types should be compared. D1 can be achieved through justifying their choice of production type in detail.

Achievement of P5, P7, P9 and P10 could use a written task asking learners to identify the terms and roles suitable for accurate quality control procedures and how this can be built into TQM. This could be linked to a case study, based around a company visit if possible. Learners would have to identify the areas where standards such as ISO 9001 are vital in industry and how the companies involved identify the relevant roles for P6 and P8 respectively. As part of this written task, learners can also draw evidence of explaining the importance of structure in the quality procedures to gain M2.

This case study or visit should then allow learners to identify and evaluate the QA procedures in operation and allow them to suggest improvements for D2.

P11 and P12 can be achieved through a written analysis of the different types of production processes and their advantages in improving productivity. This would then lead to a description of the importance of continuous improvement for P13 and also allow learners the opportunity for detailed discussion to achieve M3 at the same time. Learners should describe a given production process and the importance of the management structures present for P14 and then explain the impact effective team building and teamwork has on productivity for P15. Learners can then suggest improvements to this in detail, which would give the opportunity to achieve D3.

The achievement of P16 should be tied to an analysis of learners own workplace human resources department to produce an explanation of the key features, and also allow the opportunity to discuss why it is important for companies to follow the law, with some examples of the effects for M4. This could be linked to the importance of representation from bodies such as workers’ unions for P18.

P17 and P19 can be achieved through research into why companies should continually develop their staff and the effect that Investors in People has on encouraging employment and development.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, P2, P3, P4, M1, D1</td>
<td>Production Processes and Planning</td>
<td>A company decides to manufacture a product. Learners should analyse the possible types to produce it and identify the most suitable, justifying their selection.</td>
<td>A written task encompassing production and production planning</td>
</tr>
<tr>
<td>P5, P6, P7, P8, P9, P10 M2, D2</td>
<td>Investigation into Quality Management</td>
<td>Learners will analyse existing quality management procedures in a company (or their own company if suitable) and use the data found to suggest improvements.</td>
<td>Case study of the company they are working at or a different one if appropriate</td>
</tr>
<tr>
<td>P11, P12, P13, P14, P15 M3, D3</td>
<td>Continuously Improving Productivity</td>
<td>Learners identify the most common production methods used by companies (and their own company if appropriate) and analyse the impact that these processes have had on productivity.</td>
<td>A written task, case study.</td>
</tr>
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<tr>
<td>P16, P18, M4</td>
<td>Employers’ Rights and Employment Law</td>
<td>Learners analyse their workplaces’ employment contracts and processes, alongside existing cases brought against companies to analyse the importance and effect of the law and union’s role in defending workers’ rights.</td>
<td>A written task, case study.</td>
</tr>
<tr>
<td>P17, P19</td>
<td>Investment in People</td>
<td>Learners will identify the importance of investment in the workforce, how companies obtain IIP and what effect that has on employment.</td>
<td>A written task.</td>
</tr>
</tbody>
</table>

**Essential resources**

Case study into quality management of a sample company for learners with unsuitable employers to study their own company.

Evidence from previous employment law cases to allow learners to identify the importance of a company abiding by the law.

**Indicative reading for learners**

**Textbooks**


**Journals**

Business Review Magazine (Phillip Allan Publishers – see www.phillipallan.co.uk)

The Economist (The Economist Newspaper Group Inc)

**Websites**

BBC News [www.bbc.co.uk/business](http://www.bbc.co.uk/business)

National Learning Network [www.nln.ac.uk](http://www.nln.ac.uk)
Unit 20  Electro-pneumatic and Hydraulic Systems and Devices

Level: 3  
Unit type: Optional  
Assessment type: Internal  
Guided learning: 60

Unit introduction

An understanding of how fluid power systems are used to control the operation of machinery and equipment is important for anyone thinking of a career in engineering.

Pneumatic (pressurised air or gas) systems are widely used in manufacturing engineering to operate equipment such as packaging machines, automated assembly machines, clamping and lifting devices. There are many other everyday applications where air operated equipment is found, for example for opening doors on buses. Hydraulic (pressurised liquid) systems are used where greater amounts of power are involved, a good example of this being the linear actuators that move the arms on excavators and other types of earthmoving equipment.

This unit will give learners a broad understanding of the design and safe operation of pressurised fluid systems that use electrical control devices to make them work. This will include reading and producing simple fluid power circuit diagrams, understanding the principles of maintenance, and the use of test routines to identify faults in these systems.

Learners will investigate the impact that current legislation has on the design and safe operation of fluid power circuits, so that when carrying out practical work they are able to work safely. High pressure systems and devices, particularly air-based ones, have hidden dangers. Because hydraulic oil is carcinogenic, learners will be made aware of the regulations covering the handling and disposal/recycling of this substance.

This is followed by a look at a selection of the components used in fluid power systems and how they can be represented using universally recognised circuit diagram symbols. The components studied will include those used to generate a supply of high pressure air or hydraulic fluid, prime movers such as linear actuators (cylinders) and control devices such as valves and sensors.

Learners will be introduced to some of the calculations that need to be carried out before designing and setting up a system. These include some basic pressure and volume calculations involving gases, determination of the correct size of cylinder to produce a specified extending force, and calculation of fluid flow rates needed to keep a system operating effectively. Learners will then investigate how components can be linked together to form systems for a specific purpose.
The final section of the unit looks at how fluid power systems are maintained in service and what happens if they develop faults. The emphasis here is on applying safe working practices, using predetermined systematic schedules and keeping accurate records for future reference.

Note that the use of ‘e.g’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g’ needs to be taught or assessed.

**Learning outcomes**

**On completion of this unit a learner should:**

1. Know about the legislation, regulations and safety precautions that apply when working with fluid power systems
2. Know the construction and operation of fluid power devices and how they are represented as symbols in circuit diagrams
3. Be able to apply fluid power principles in the design of circuits
4. Be able to carry out maintenance, inspection, testing and fault-finding on fluid power systems.
Unit content

1 Know about the legislation, regulations and safety precautions that apply when working with fluid power systems


Safety precautions: risk assessment of fluid power systems; assembling and testing electro-pneumatic and hydraulic systems and devices, e.g. isolation of services (such as electrical, air, oil), escape of fluids at high pressure which may cause contact injury, hydraulic oil contact with the skin, sudden movement of linear actuators causing entrapment injuries; personal protective equipment (PPE), e.g. safety glasses, gloves, overalls, footwear

2 Know the construction and operation of fluid power devices and how they are represented as symbols in circuit diagrams

Fluid power devices: fluid conditioning, e.g. supply tank, filter, pump, cooler, compressor, dryer, receiver, accumulator; fluid supply, e.g. pipework, fittings, seals, drainage points; electrical supply systems, e.g. mains, low voltage regulated power supply units, AC, DC; fluid control valves, e.g. directional (manual and solenoid), pilot, 4 port, 5 port, pressure reducing, non-return, flow rate; actuators linear, rotary; motors e.g. electric, air, hydraulic; position sensors, e.g. reed switch, pressure switch, inductive, microswitch; system control, e.g. programmable logic controller (PLC), electro mechanical

Symbols: relevant and current standards, e.g. BS3939, BS ISO 1219-1:2012, European Fluid Power Committee (CETOP); symbols for common components, e.g. fluid conditioning, fluid supply, electrical supply, control valves, actuators, motors, sensors, control

Circuit diagrams: diagrams, e.g. pneumatic, hydraulic, block diagrams, system layout, displacement step diagrams; reference material, e.g. component and equipment data sheets, BS ISO 1219-1:2012, software (such as FluidSIM or Automation Studio)
3 Be able to apply fluid power principles in the design of circuits

Fluid power principles: properties and behaviour of air and hydraulic fluids; gas laws, e.g. Boyle’s, Charles’, Gay-Lussac’s, general gas, dew point; fluid flow, e.g. Bernoulli’s principle, volumetric rate, receiver volume, actuator flow requirements; fluid pressure e.g. units of measurement, Pascal’s law, inlet and outlet pressure, pressure drop, actuator efficiency, clamping force; formulae \( P_1 V_1 T_2 = P_2 V_2 T_1 \), displaced volume = piston area × stroke,

volumetric flow rate = \( \frac{\text{displaced volume}}{\text{time}} \),

absolute pressure = gauge + atmospheric pressure,

force = pressure × area, actuator force = pressure × area × efficiency)

Circuits: pneumatic, e.g. multi-cylinder sequential operation, single-cylinder reciprocation with dwell, position and clamp an object using a two-cylinder arrangement, rotary actuator with reversing action; hydraulic, e.g. multi-cylinder sequential operation, single-cylinder reciprocation with dwell and regeneration, hydraulic motor with reversing action

4 Be able to carry out maintenance, inspection, testing and fault-finding on fluid power systems

Maintenance: routines, e.g. frequency of maintenance, manuals and reference documentation, keeping of accurate records using paper- or software-based systems; components (electro-pneumatic, hydraulic); systems, e.g. electro-pneumatic, electro-hydraulic

Inspection: functional, e.g. at component level, as a system, performance against specification; keeping of accurate records; report, e.g. component drawing, system circuit diagram, digital images, inspection checklist, record of visual observations made against checklist, conclusions, recommendations

Testing: performance, e.g. against specification, reliability; keeping of accurate records; report, e.g. system circuit diagram, system specification, test schedule, list of test equipment, record test results, record visual observations, compare test results with system specification, recommendations for future actions

Fault finding: identify faults in fluid power systems, e.g. manual diagnosis, visual examination, unit substitution, input to output, injection and sampling, half-split technique, six-point technique, self-diagnostic techniques using programmable electronic equipment, effect of malfunctions; fault-finding aids, e.g. functional charts, diagrams, flow charts, troubleshooting charts, component data sheets, operation and maintenance manuals, specialised equipment; record faults, e.g. paper based, software based, analyse data; report, e.g. system circuit diagram, record test results, record visual observations, compare test results with system specification, record faults and cross reference to circuit diagram, identify type of fault, strategy for rectification of fault
### Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<td>P1</td>
<td>list the aspects of health and safety legislation and regulations that apply when working with given fluid power equipment and systems</td>
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<tr>
<td>P2</td>
<td>describe the safety precautions that apply when working with fluid power equipment and systems</td>
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<tr>
<td>P3</td>
<td>describe, with the aid of suitable diagrams, the construction and operation of a given electro-pneumatic device and a given electrohydraulic device</td>
<td>M1 compare the construction and operation of a pneumatic system with that of a hydraulic system</td>
<td>D1 assess the relevance of current standards, such as CETOP, to the construction and operation of fluid power devices</td>
</tr>
<tr>
<td>P4</td>
<td>use standards to identify electro-pneumatic and hydraulic components shown as symbols in given circuit diagrams and reference materials</td>
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<td><strong>P5</strong> carry out calculations that relate to the fluid power principles used in the design of circuits</td>
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<tr>
<td><strong>P6</strong> produce a circuit diagram to meet a given electro-pneumatic system specification</td>
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<tr>
<td><strong>P7</strong> produce a circuit diagram to meet a given hydraulic system specification</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> use routines and carry out maintenance on given electro-pneumatic and hydraulic components and a given electro-pneumatic or electro-hydraulic system</td>
<td><strong>M2</strong> explain the routines used when carrying out maintenance on a given electro-pneumatic or electro-hydraulic system</td>
<td><strong>D2</strong> evaluate the use of self-diagnostic techniques to monitor the performance of fluid power systems used in industry.</td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> carry out inspection, testing and fault-finding on a given electro-pneumatic or electrohydraulic system in line with checklists.</td>
<td><strong>M3</strong> produce a report of showing findings.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

It may be appropriate to structure the assessment of this unit as five assignments, using four to cover the pass and merit criteria and the fifth one the two distinction criteria.

The first assignment could cover P1 and P2 and should be structured so that learners remain focused on the content of learning outcome 1. Learners are expected to use their own words when referring to legislation and, while much of their research will be done using the internet, it is important that what they present is not just a simple cut and paste exercise. Evidence to support knowledge of safety precautions could be generated by giving learners a list of situations/scenarios and then asking them to detail what needs to be done to work safely. This leads into risk assessment and learners could be asked to carry out an assessment for equipment which they will be using later in the unit.

Grading criteria P3, P4, M1 and D1 complement each other and could be assessed through a second assignment that covers the whole of the content for learning outcome 2. P3 asks for information about the construction and operation of equipment and, provided that any written explanation is supported by diagrams there is no requirement for learners to present fully detailed drawings of the devices considered.

To meet the requirements of P4, learners could be given a suitable set of circuit diagrams and manufacturers’ reference material for the equipment described for P3. This would determine the amount of components and symbols needed to meet the requirement of P4. Examples of such devices are found in the unit content and delivery guidance. M1 encompasses P3 and P4 and requires a comparison of the construction and operation of the two systems. This comparison can be extended to assess the relevance of standards such as ISO and CETOP to the construction and operation of fluid power devices.

P5, P6 and P7 are linked and could be assessed using a third assignment that will involve calculation and the production of circuit diagrams which meet given design specifications. These can be hand drawn but it is better if learners use a software package so that simulation can be carried out to ensure correct operation of the circuits. This could be evidenced in the form of screen prints consolidated by a witness statement or observation record.

Grading criteria P8, P9, M2 and D2 could be assessed using a fourth assignment. Evidence of learners’ competence when carrying out practical tasks will need to be recorded using witness statements, observation records and digital images.

The tasks set to generate evidence for P8 should involve the use of a small range of components and just one fluid power system (i.e. pneumatic or hydraulic).

Similarly, when producing evidence for P9, it is only necessary to work with one type of system. Both criteria require learners to keep accurate records and use relevant documentation in addition to carrying out the practical tasks. Learners who built the circuits that they designed to achieve P6 and P7 could work on these when gathering evidence for P8 and P9.

M2 and M3 build on P8 and P9 requiring an explanation and a report showing findings. Finally, D2 requires an evaluation of self-diagnostic techniques to monitor performance. This could include, for example, electronic programmable equipment to carry out the monitoring and an evaluation of its effectiveness.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2</td>
<td>Legislation and Safety Precautions</td>
<td>Learners to carry out a risk assessment for fluid power equipment in an engineering situation.</td>
<td>A written assignment in which learners detail the legislation and safety precautions that apply to a piece of fluid power equipment that they are going to use.</td>
</tr>
<tr>
<td>P3, P4, M1, D1</td>
<td>Construction and Operation of Fluid Power Devices</td>
<td>Use and interpret circuit diagrams to identify and describe the operation of fluid power devices and components.</td>
<td>A written assignment with tasks requiring learners use diagrams to describe fluid power devices and identify components.</td>
</tr>
<tr>
<td>P5, P6, P7</td>
<td>Fluid Power Principles and Circuits</td>
<td>Learners have been asked to produce circuit diagrams to meet the requirements of a customer specification in an engineering situation.</td>
<td>A practical assignment requiring learners to produce two circuit diagrams and carry out calculations.</td>
</tr>
<tr>
<td>P8, P9, M2, M3, D1, D2</td>
<td>Carrying Out Fluid Power Maintenance, Inspection, Testing and Fault-finding</td>
<td>Learners have been asked by their supervisor to carry this out on fluid power systems.</td>
<td>A practical assignment supported by a logbook/report of activities carried out plus observation records.</td>
</tr>
</tbody>
</table>
**Essential resources**

To meet the needs of this unit it is essential that centres have access to the following:

- industrial-standard electro-pneumatic and hydraulic equipment and systems
- fluid power circuit design software, e.g. FluidSIM or Automation Studio
- test equipment and measuring instruments
- relevant British and international standards
- health and safety publications.

**Indicative reading for learners**

**Textbooks**


Unit 21: Engineering Drawing for Technicians

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

It is important that when a product has been designed it is manufactured correctly and to specification. To achieve this, it is crucial that the people making the product in a workshop are provided with well-presented engineering drawings, produced to international standards and conventions. This avoids errors of interpretation that can lead to the scrapping of expensive parts.

An understanding of how graphical methods can be used to communicate information about engineering products is an important step for anyone thinking of taking up a career in engineering. This unit gives learners an introduction to the principles of technical drawings and their applications using hand drawing and computer-aided design (CAD) techniques.

Learners will start by carrying out freehand sketching of simple engineering products using pictorial methods that generate three-dimensional (3D) images. A range of standard components, such as fixing devices, will be sketched together with other solid and hollow items. Learners are then introduced to a more formalised drawing technique that conforms to British Standards and will put this into practice through a number of drawing exercises. A consistent presentation style will be used as learners draw single part components and simple engineering assemblies.

These drawings will contain all the information needed to manufacture or assemble the product, including information such as dimensions, manufacturing notes and parts lists. The use of conventions to represent standard items will be investigated, such as screw threads and springs in mechanical type drawings or circuit symbols such as solenoids and resistors in electrical/electronic type drawings.

Having learned the principles of engineering drawing, learners will then move on to using a two-dimensional (2D) CAD system for the production of drawings using basic set-up, drawing and editing commands. The first task is to produce a drawing template which can be saved to file, as this reinforces the concept of standardisation and consistency of presentation. This is followed by drawing exercises of single-part components, a simple multi-part assembly and circuit diagrams.

Overall, the unit will develop learners’ ability to create technical drawings and allow them to compare the use of manual and computer aided methods of producing engineering drawings.
Learning outcomes

On completion of this unit a learner should:

1. Be able to sketch engineering components
2. Be able to interpret engineering drawings that comply with drawing standards
3. Be able to produce engineering drawings
4. Be able to produce engineering drawings using a computer-aided design (CAD) system.
Unit content

1 Be able to sketch engineering components

*Sketches*: regular solids, e.g. cube, rectangular block, 900 angle bracket; hollow objects, e.g. circular tube, square section tube; standard components, e.g. nuts, bolts, screws, pulleys; engineering components, e.g. pulley support bracket, machine vice

*Sketching techniques*: sketching equipment, e.g. paper (plain, squared, isometric), pencil, eraser; pictorial, e.g. oblique drawing (cavalier and cabinet), isometric; orthographic, e.g. single and linked views; sketching in good proportion; dimensions, e.g. overall sizes, detail

*Benefits and limitations of using pictorial techniques*: benefits, e.g. speed of production, visual impact; limitations, e.g. lengths and shapes not true, not produced to a recognised standard, dimensions difficult to read; consequences of interpretation errors, e.g. incorrect manufacture, incorrect assembly, cost to scrap

2 Be able to interpret engineering drawings that comply with drawing standards

*Interpret*: obtaining information from engineering drawings, e.g. component features, dimensions and tolerances, surface finish, manufacturing detail, assembly instructions, parts list, circuit operation

*Drawing standards*: British Standards, e.g. BS 8888, BS 3939, BS 2917, PP 7307; company-standardised layouts, e.g. drawing number, title and issue number, projection symbols (first angle, third angle), scale, units, general tolerances, name of person responsible for producing drawing; line types, e.g. centre, construction, outline, hidden, leader, dimension; lettering, e.g. titles, notes; orthographic projection, e.g. first angle, third angle; views, e.g. elevation, plan, end, section, auxiliary; representation of common features, e.g. screw threads, springs, splines, repeated items; section views, e.g. hatching style, webs, nuts, bolts and pins, solid shafts; symbols and abbreviations, e.g. A/F, CHAM, Φ, R, PCD, M; circuit symbols, e.g. electrical, electronic, hydraulic, pneumatic

3 Be able to produce engineering drawings

*Detail drawings of single-piece engineering components*: projection method; scale; title block; line work; views; sections; dimensions; tolerances; surface finish; notes

*Assembly drawings*: line work, e.g. centre lines, construction, outline, cutting plane, sectional view, hatching; representation of standard components, e.g. nuts, bolts, screws, keys; parts referencing, e.g. number referencing, parts list; notes, e.g. assembly instructions, installation features, operating instructions

*Circuit diagrams*: circuits, e.g. electrical, electronic, hydraulic, pneumatic; components, e.g. transformers, rectifiers, solenoids, resistors, capacitors, diodes, valves, pumps, actuators, cylinders, receivers, compressors
4 Be able to produce engineering drawings using a computer aided design (CAD) system

Prepare a template: standardised drawing sheet, e.g. border, title block, company logo; save to file

CAD systems: computer systems, e.g. personal computer, networks; output devices, e.g. printer, plotter; storage, e.g. server, hard disc, CD, pen drive; 2D CAD software packages, e.g. AutoCAD, Microstation, Cattia, Pro/Engineer, Pro/Desktop

Produce engineering drawings: set-up commands, e.g. extents, grid, snap, layer; drawing commands, e.g. coordinate entry, line, arc, circle, snap, polygon, hatch, text, dimension; editing commands e.g. copy, move, erase, rotate, mirror, trim, extend, chamfer, fillet

Store and present engineering drawings: save work as an electronic file, e.g. hard drive, server, pen drive, DVD; produce paper copies, e.g. print, plot, scale to fit
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<thead>
<tr>
<th>Assessment and grading criteria</th>
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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong> create sketches of engineering components using a range of techniques</td>
<td><strong>M1</strong> assess the suitability of the different techniques for the sketches</td>
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</tr>
<tr>
<td><strong>P2</strong> describe the benefits and limitations of using pictorial techniques to represent a given engineering component</td>
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</tr>
<tr>
<td><strong>P3</strong> interpret the main features of a given engineering drawing which complies with drawing standards</td>
<td><strong>M2</strong> explain in the importance of working to recognised standards when producing engineering drawings</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> produce detailed drawings of three given single-piece components that comply with drawing standards</td>
<td><strong>M3</strong> explain how the sketches comply with drawing standards</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong> produce an assembly drawing of a product containing three parts that complies with drawing standards</td>
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</tr>
</tbody>
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### Assessment and grading criteria

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<tbody>
<tr>
<td><strong>P6</strong> produce a circuit diagram that complies with drawing standards, with at least five different components which use standard symbols</td>
<td><strong>M4</strong> explain in how a given engineering drawing would be used and the reasons it is suitable for its intended audience</td>
<td><strong>D1</strong> evaluate the use of different methods of producing engineering drawings including manual and computer aided methods</td>
</tr>
<tr>
<td><strong>P7</strong> prepare a template drawing of a standardised A3 sheet using a CAD system and save to file</td>
<td><strong>M5</strong> explain the hardware components of a typical industry standard CAD system.</td>
<td><strong>D2</strong> evaluate the functionality of a CAD software package.</td>
</tr>
<tr>
<td><strong>P8</strong> produce, store and present 2D CAD drawings of a given single-piece component and an assembly drawing of a product containing three parts.</td>
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</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment of this unit could be through the use of five assignments. To achieve a pass, learners are expected to show competence in a number of graphical techniques and to be able to apply these to the production of engineering drawings which meet recognised standards.

The first assignment, to cover P1, P2 and M1, could consist of a small portfolio of sketches and written descriptions. Items drawn must include regular solids and hollow objects, standard and engineering components. The techniques used must be valid and involve sketching equipment, pictorial and orthographic representation and sketching in good proportion with the addition of some dimensions (as specified in the unit content). An assessment of these techniques will meet the requirement for M1.

The second assignment, to cover P3 and M2, will need to be carefully structured and should be based on a drawing of a component or assembly rather than a circuit diagram so that the unit content can be properly covered. M2 builds on the evidence presented for P3 and these two criteria could be assessed using a single assignment. The wider issues of standardisation and manufacturing for the global market place should be addressed with learners supporting their explanations with case study evidence.

The third assignment could cover P4, P5 and M3 with the three single-piece components in P4 being used for the assembly drawing in P5. This would then make the assignment more realistic in terms of what happens in industry. M3 would require an explanation of how the sketches in P4 comply with drawing standards.

The fourth assignment could cover P6, M4 and D1, with learners being given a choice of the type of circuit they produce depending on their interest (i.e. from electrical, electronic, hydraulic and pneumatic). The circuit can be drawn by hand but using CAD may be the preferred method if a library of components is available. M4 requires an explanation of the use of engineering drawings to communicate information effectively. D1 could be carried out as a separate task, requiring an evaluation of the various drawing techniques used by learners and link directly with the criteria P1, P5, P6 and P8. To add depth to their evidence, learners could be asked to look more widely at what is used in industry – particularly the use of 3D CAD systems which generate solid models. This would then bring them full circle back to the start of the unit, where they were producing pictorial sketches.

P7, P8, M5 and D2 can be covered by a fifth assignment, which could ask for increased competence in the application of standards when producing drawings. To help authenticate learners’ work, additional evidence could be in the form of witness statements, tutor observation records and ‘screen dumps’ which show the range of commands used during the development of the drawings. M5 and D2 could form a separate task as part of this assignment, requiring an explanation of CAD hardware and an evaluation of CAD software functionality.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
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<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1</td>
<td>Producing Engineering Sketches</td>
<td>Learners have been asked to produce sketches of a range of different objects.</td>
<td>A practical assignment requiring learners to produce a portfolio of engineering sketches with accompanying written descriptions.</td>
</tr>
<tr>
<td>P3, M2</td>
<td>Interpreting and Using Drawing Standards</td>
<td>Learners have to read and interpret an engineering drawing in order to report the key features of the component, circuit or assembly to a colleague.</td>
<td>A written assignment for which learners need to produce a short report detailing the main features of a given engineering drawing that complies with drawing standards. A further task would require them to explain the importance engineering standards.</td>
</tr>
<tr>
<td>P4, P5, M3</td>
<td>Producing Engineering Drawings</td>
<td>Learners need to produce an engineering drawing of three components and an assembly drawing for use by the manufacturing department of their company.</td>
<td>A practical assignment in which learners produce component and assembly drawings.</td>
</tr>
<tr>
<td>P6, M4, D1</td>
<td>Producing Circuit Drawings</td>
<td>Learners need to produce a circuit diagram for use by the manufacturing department of their company.</td>
<td>A practical assignment in which learners produce a circuit diagram.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
<td>Scenario</td>
<td>Assessment method</td>
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</tr>
<tr>
<td>P7, P8, M5, D2</td>
<td>Producing Engineering Drawings Using CAD</td>
<td>Learners need to prepare and produce 2D CAD drawings for use by the manufacturing department of their company.</td>
<td>A practical assignment in which learners produce 2D CAD drawings of a component and an assembly.</td>
</tr>
</tbody>
</table>

**Essential resources**

To meet the needs of this unit, it is essential that centres have, or have access to, manual drawing equipment and a CAD system that uses a 2D commercial engineering software package. Centres will also need extracts and illustrations from appropriate drawing standards and conventions.

**Indicative reading for learners**

**Textbooks**

<table>
<thead>
<tr>
<th><strong>Unit 22:</strong></th>
<th><strong>Computer-aided Drafting in Engineering</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level:</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Unit type:</strong></td>
<td>Optional</td>
</tr>
<tr>
<td><strong>Assessment type:</strong></td>
<td>Internal</td>
</tr>
<tr>
<td><strong>Guided learning:</strong></td>
<td>60</td>
</tr>
</tbody>
</table>

**Unit introduction**

Computer-aided drafting is fast becoming the primary means of communicating design information in many industry sectors, particularly in engineering and manufacturing. Two-dimensional (2D) CAD drawings and three-dimensional (3D) CAD data can be shared with computer numerical control (CNC) machines using computer-aided manufacturing (CAM) software. 3D models can be rendered to produce photo-realistic representations, or can be animated to produce moving views of products and components as they would appear in service. Additionally, models can be used to analyse features such as mass, volume and mechanical properties.

This unit will enable learners to produce a variety of CAD drawings, from single-part 2D components to complex 3D models. Advanced techniques, such as using pre-prepared symbols to construct circuit diagrams and assembly drawings, will provide opportunities for learners to develop their skills. Learners will investigate the use of CAD in industry, the hardware and software required and the links with other software packages. In doing this, learners will appreciate the advantages of CAD over more conventional methods of drawing production.

Finally, learners will generate 3D models, make comparison with 2D CAD drawings and evaluate the impact of this technology on manufacturing companies and their customers.

The unit as a whole provides an opportunity to carry out practical CAD activities using a full range of commands and drawing environments. In addition, learners will gain an understanding of the use and impact of CAD on the manufacturing industry.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Know the national and international standards and conventions that CAD drawings and design need to comply with
2. Understand the advantages of using CAD in comparison with other methods
3. Know about the software and hardware required to produce CAD drawings
4. Be able to produce and interpret CAD drawings
5. Be able to use CAD software to produce 3D drawings and views.
Unit content

1 Know the national and international standards and conventions that CAD drawings and design need to comply with

Requirements of current national and international standards and conventions:

Features of CAD drawings that need to comply with national and international standards: drawing sheet sizes and layouts, projection – first and third angle types of line, lettering and numbering, dimensioning, section cross hatching

Standard representations: welding symbols, electrical symbols, pneumatic/hydraulic symbols, mechanical symbols

2 Know the advantages of using CAD in comparison with other methods

Advantages of CAD: quality; accuracy; time; cost; electronic transfer of information; links with other software, e.g. CAD/CAM, rendering software, animation software, finite element analysis (FEA)

Other methods: manual drafting; model making

3 Know about the software and hardware required to produce CAD drawings

Software: operating systems; CAD software packages, e.g. AutoCAD, AutoCAD/Inventor, Microstation, Catia, Pro/ENGINEER, Solidworks; minimum system requirements, e.g. hard disk space, memory required, processor, video card

Hardware: keyboard; mouse; other input devices, e.g. light pen, digitiser, joystick, thumbwheel; monitor; printer; other output devices, e.g. plotter, rapid prototyping; storage, e.g. floppy disk, hard disk, memory stick, CD, network

4 Be able to produce and interpret CAD drawings

CAD drawings: orthographic projections; circuit diagrams, e.g. hydraulic, pneumatic, electronic; exploded/assembly drawing; standards, e.g. BS 8888, BS 3939, BS 2917

Commands: absolute/relative/polar coordinates; features, e.g. linetypes, grids, snaps, circle, text, hatching, dimensioning, layers/levels, colour; viewing, e.g. zoom, pan; inserting other drawings, e.g. symbols, blocks; modifying, e.g. copy, rotate, move, erase, scale, chamfer, fillet

Interpret: determine properties of drawn objects, e.g. list, distance, area, volume

5 Be able to use CAD software to produce 3D drawings and views

3D environment: 3D views, e.g. top, front, side, isometric

3D models: 3D techniques, e.g. addition and subtraction of material, extrude, revolve, sweep, 3D coordinate entry (x, y, z), wire frame drawing, 2D to 3D (thickness, extrusion); surface models; solid models
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong> describe the requirements of national and international standards and conventions relating to engineering drawing practice</td>
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</tr>
<tr>
<td><strong>P2</strong> explain which features of CAD drawings need to comply with national and international standards</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> explain the advantages, compared to other methods, of producing drawings electronically using a CAD package</td>
<td><strong>M1</strong> explain the relationship between CAD and other software/hardware used in manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> describe the software and hardware that are required to produce CAD drawings</td>
<td></td>
<td><strong>D1</strong> justify the use of CAD in a manufacturing company</td>
<td></td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

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<tr>
<td><strong>P5</strong> produce 2D CAD detail drawings of five components that make up an assembly or sub-assembly to given standards, using appropriate commands</td>
<td><strong>M2</strong> explain how the range of commands used to produce CAD drawings can impact drawing production</td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> produce a circuit diagram containing at least five components to appropriate standards, using appropriate commands</td>
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<td></td>
</tr>
<tr>
<td><strong>P7</strong> produce an assembly drawing and exploded view of an assembly or sub-assembly containing at least five parts, using appropriate commands</td>
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<td></td>
</tr>
<tr>
<td><strong>P8</strong> interpret the properties of an engineering component or circuit from a given CAD drawing</td>
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<td></td>
</tr>
<tr>
<td><strong>P9</strong> construct a 3D CAD drawing as a surface and solid model.</td>
<td><strong>M3</strong> explain how 3D CAD models can be used in the design process.</td>
<td><strong>D2</strong> evaluate the impact of the use of 2D and 3D CAD models on final design requirements.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

An assignment could cover P1 and P2 and should be structured so that learners remain focused on the content of learning outcome 1. Learners are expected to use their own words when referring to the national and international standards and conventions. While much of their research will be done using the internet, it is important that what they present is not just a simple cut and paste exercise. Evidence to support knowledge of which features of CAD drawings comply with national and international conventions could be generated by giving learners drawings which highlight the details required for meeting National and International conventions.

The assessment evidence for P3 and P4 could be produced through a case study or through studying the company in which learners may be employed. Typically, it would take the form of a written report or presentation. To achieve P3, learners must demonstrate an understanding of how CAD is used in comparison with more traditional drawing methods, stating its advantages and explaining how CAD systems can be linked with other software. A description of basic hardware and software requirements to operate a CAD system will be required to achieve P4.

The remaining pass criteria could be evidenced through a series of competence-based practical activities. Evidence could be in the form of witness statements, tutor observation records or a portfolio, although it is likely that electronic files will be used for the majority of the assessment. Screen dumps can often be a good source of evidence to show the range of commands used during the development of the drawings. The process evidence for these remaining pass criteria (P5 to P9) could be obtained from further assignments. In the first of these, learners would be required to produce five separate CAD drawings of the components which make up an assembly or sub-assembly. The full range of commands must be used and the drawings should be dimensioned to an appropriate standard, enabling P5 to be achieved. These drawings could then be used to produce an assembly and exploded view drawing (P7).

A further assignment would require production of a circuit diagram to achieve P6. This might reflect learners’ occupation or area of interest and should be assembled from symbols previously introduced by the tutor and/or externally sourced. This assignment could also ask learners to interpret and provide a summary of the information contained in a given detail drawing or circuit diagram (P8).

The final assignment would require production of a single 3D model using both surface and solid modelling techniques to enable achievement of P9. This might be a 3D version of one of the part drawings used as evidence for the assembly and exploded view drawing.

To achieve a merit grade, learners will need to look beyond how drawings are produced and evaluate their use and application. This will typically be through looking more closely at the relationship between CAD and other software. Learners should explain how linking CAD to other software/hardware impacts on an organisation (for example improving production, reducing waste, reducing lead times). This will build on the evidence generated for P3 and enable the M1 merit criterion to be achieved.

An explanation of the range of commands for criterion M2 and how they impact on drawing production in terms of efficiency (for example speed, accuracy, repeatability) links with P5, P6 and P7. Similarly, knowledge for the M3 criterion of how 3D models can be used in the design process links with the 3D activity in P9.
To achieve distinction criterion D1, learners should justify the use of CAD and will need to analyse other factors (for example disadvantages, costs, training requirements). This links with P3 and P4 as well as the M1 and M2 criteria. Learners should evaluate the relative merits of using CAD software. This could be as part of the case study outlined as possible evidence for the P3 criterion.

To achieve the D2 criterion learners will need to evaluate 2D and 3D drawings from a customer perspective. This links directly with the P9 and M3 criteria. Learners will need to compare and contrast the impact on customers of producing drawings using 2D and 3D CAD and how customers might use the information produced.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 and P2</td>
<td>National and International Standards Report</td>
<td>Learners to research national and international standards and relate to engineering CAD drawing practice.</td>
<td>A report describing national and international standards and an explanation of CAD features that need to comply with these standards.</td>
</tr>
<tr>
<td>P3, P4, M1 and D1</td>
<td>CAD Report</td>
<td>Learners to research and compare the use of CAD with other methods and determine the software and hardware required to produce CAD drawings; in addition an investigation of how CAD links to other software and hardware and a justification of the use of CAD in manufacturing.</td>
<td>A report containing written responses about the use of CAD and alternative methods; in addition the software and hardware requirements of a CAD system should be listed and explained. An explanation of how CAD links with other software and hardware should support a justification of the use of CAD in a manufacturing context.</td>
</tr>
<tr>
<td>P5, P7 and M2</td>
<td>CAD Portfolio</td>
<td>Learners to create an assembly drawing of at least five parts and detail CAD drawings of the five components; in completing the task learners should be able to explain how they used a range of commands in the CAD software to efficiently produce drawings.</td>
<td>A portfolio of five component drawings and an assembly drawing containing the five individual parts; in addition a short report containing written responses and/or screen dumps explaining how a range of CAD commands were used to efficiently produce the completed drawings.</td>
</tr>
</tbody>
</table>
Essential resources

Centres will need to have access to a suitably equipped IT facility with access to a printer/plotter. Access to software with 2D and 3D capabilities, such as AutoCAD and Inventor is also required. While general graphics packages would not be suitable, any CAD software capable of generating the evidence required for this unit would be acceptable.

Indicative reading for learners

Textbooks


Conforti F – Inside Microstation (Delmar, 2005) ISBN 9781418020842


Yarwood A – Introduction to AutoCAD 2012 (Routledge, 2011) ISBN 9780080969473
## Unit 23:
### Advanced Mechanical Principles and Applications

<table>
<thead>
<tr>
<th>Level:</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit type:</td>
<td>Optional</td>
</tr>
<tr>
<td>Assessment type:</td>
<td>Internal</td>
</tr>
<tr>
<td>Guided learning:</td>
<td>60</td>
</tr>
</tbody>
</table>

### Unit introduction

This unit will build on learners’ knowledge of underpinning mechanical principles and the way they affect the design, operation, testing and servicing of machines and mechanisms.

The component parts of a mechanical system are very often subjected to loads and may be used to transmit force. It is essential that they are fit for purpose so that costly breakdowns and accidents are avoided. Design engineers must be able to predict the stresses to which engineering components will be subjected and ensure an appropriate level of safety.

Learning outcomes 1 and 2 will broaden learners’ knowledge of stress analysis to include stress due to bending, stress due to torsion and the effects of two-dimensional (2D) and three-dimensional (3D) loading.

Learners sometimes have difficulty with the concepts of resultant and relative velocity. Learning outcome 3 seeks to clarify how these concepts are determined through the techniques of vector addition and vector subtraction. These are then applied to the operation of plane linkage mechanisms to determine the output characteristics for given input conditions.

The aim of learning outcome 4 is to give an understanding of mechanical oscillations in engineering systems. The concept of simple harmonic motion is introduced and expressions are derived for its parameters. These are then applied to freely vibrating systems such as mass-spring systems and the simple pendulum.

The unit as a whole provides an opportunity for investigative, relevant and active study that will enhance learners’ ability to solve engineering problems.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Be able to determine the effects of uniaxial and complex loading on engineering components
2. Be able to determine the stress due to bending in beams and torsion in power transmission shafts
3. Be able to determine relative and resultant velocity in engineering systems
4. Be able to determine the characteristics of simple harmonic motion in engineering systems.
Unit content

1 Be able to determine the effects of uniaxial and complex loading on engineering components

Uniaxial loading: expressions for longitudinal and transverse strain; application of Poisson’s ratio; determination of dimensional changes in plain struts and ties

Complex loading: expressions, e.g. strain in \( x \) and \( y \) directions due to 2D loading, strain in \( x \), \( y \) and \( z \) directions due to 3D loading; changes, e.g. dimensional in rectangular plates, dimensional and volume for cubic elements

2 Be able to determine the stress due to bending in beams and torsion in power transmission shafts

Direct stress due to bending: expressions for second moment of area of solid and hollow rectangular and circular beam sections; application of bending equation \( \sigma = \frac{MI}{y} \) to determine stress due to bending and radius of curvature at a beam section; determination of factor of safety in operation

Shear stress due to torsion: expressions for polar second moment of area of solid and hollow circular transmission shaft sections; application of torsion equation \( \tau = \frac{T}{J} \) and expression for power transmitted (power = \( T\omega \)) to determine induced shear stress and angle of twist; determination of factor of safety in operation

3 Be able to determine relative and resultant velocity in engineering systems

Resultant and relative velocity: vector addition of velocities; resultant velocity of a body with simultaneous velocities in different directions; vector subtraction of velocities; relative velocity between objects moving simultaneously in different directions; construction of space diagrams and velocity vector diagrams

Plane mechanisms: e.g. slider-crank and inversions, four-bar linkage and inversions, slotted link quick return mechanism, Whitworth quick-return mechanism; construction of diagrams, e.g. space diagram, velocity vector diagram, determination of output motion
4 Be able to determine the characteristics of simple harmonic motion in engineering systems

*Simple harmonic motion generation:* general equations for simple harmonic motion derived from a consideration of uniform circular motion, e.g. expressions for circular frequency, displacement with time, velocity with time, velocity with displacement, acceleration with time, acceleration with displacement, periodic time, frequency of vibration; application to mechanical systems where output simple harmonic motion is generated by input uniform circular motion, e.g. scotch yoke mechanism; parameters to be determined, e.g. frequency of vibration, periodic time, displacement, velocity and acceleration at a given instant

*Vibrating mechanical systems:* systems (mass-spring, simple pendulum); expressions for circular frequency in terms of system parameters; application of general equations for simple harmonic motion, e.g. natural frequency of vibration, periodic time, velocity and acceleration at a given instant
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td><strong>P1</strong> determine the dimensional effects of uniaxial loading on a plain structural component and 2D loading on a rectangular plate</td>
<td><strong>M1</strong> determine the dimensional effects and change in volume for a given element of an engineering component when subjected to 3D loading</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong> determine the maximum stress due to bending, factor of safety in operation and minimum radius of curvature for a simply supported beam carrying a given concentrated load and a uniformly distributed load</td>
<td><strong>M2</strong> compare the effects on a rectangular section beam’s load-carrying capacity of increasing the breadth and increasing the depth by given amounts</td>
<td><strong>D1</strong> compare the saving in weight and the reduced torque transmission capacity for a hollow power transmission shaft as its internal diameter is increased</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> determine the maximum shear stress, factor of safety in operation and angle of twist for a mechanical power transmission shaft when transmitting given power at a given speed</td>
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## Assessment and grading criteria

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<td><strong>P4</strong> determine the resultant velocity of an object when moving simultaneously with velocities in two different directions and its velocity relative to a second object moving in the same plane in a third direction</td>
<td><strong>M3</strong> determine the output velocity of a given quick-return mechanism for given input conditions</td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong> determine the output motion of a slider-crank mechanism and a four-bar linkage mechanism for given input conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> determine the periodic time and the displacement, velocity and acceleration at a given instant of the simple harmonic motion generated by circular motion of given parameters</td>
<td><strong>M4</strong> evaluate the output motion of the slider in a slider-crank mechanism with uniform input motion of the crank, for compliance with the conditions necessary for it to describe simple harmonic motion.</td>
<td><strong>D2</strong> determine from test data the effective contributory mass of the spring in an oscillating mass-spring system.</td>
</tr>
<tr>
<td><strong>P7</strong> determine the circular frequency, the natural frequency of vibration and the maximum velocity and acceleration for a mass-spring system and a simple pendulum with given parameters.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Ideally, assessment of this unit will be achieved through applying the mechanical principles covered to relevant engineering settings. This could be achieved through integration with other engineering principles units, practical work that provides learners with opportunities to produce individual evidence for assessment and individual project/assignment tasks. Whichever approach is taken, it is important to ensure that the criteria are achieved autonomously. Where centres consider a test/examination is necessary to achieve authentic evidence, they need to ensure that the test items are set in a way to enable the criteria to be met in full. Centres also need to consider how such an assessment will provide opportunities to meet the merit and distinction criteria and how to provide learners with further learning and assessment should they initially fail to achieve in the test/examination.

If learners make an arithmetic error in the solution to a problem, it is for the centre to decide the significance of such an error, assess the work accordingly and provide suitable feedback. For example, if a learner has chosen the correct approach and manipulated the necessary formulae and data correctly but has made and carried through a minor arithmetic error, then the final ‘inaccurate’ solution to the problem may be deemed to be good enough to meet the criterion. However, if the final solution to the problem is so obviously wrong that it should have prompted further checks for accuracy, then the solution could be deemed to be unacceptable and reassessment considered. The incorrect application of units and/or dimensions is a typical cause of such major errors, which can lead to relatively large scale errors of the magnitude 10³ or greater.

Assuming that the unit is delivered in the order of the learning outcomes, a first assignment could provide an opportunity to achieve the pass criterion P1 by means of tasks to determine the dimensional effects of uniaxial and 2D loading. These could be followed by a task to determine the dimensional effects of 3D loading and corresponding change in volume for achievement of the M1, all to be documented in a short report and authentication of the evidence being presented.

A second assignment might contain a task to determine the stress and curvature in a loaded beam (P2) and a task to determine the shear stress and angle of twist in a power-transmission shaft for given operating conditions (P3), suitably documented. A third task, to achieve criterion M2, could be to examine the effects of increasing the breadth and depth of a rectangular beam section on its second moment of area and hence also on its load-carrying capacity. A fourth task to achieve D1 might be to compare the saving in weight and the reduction in torque transmission capacity as the internal diameter of a hollow transmission shaft is increased.

P4 and P5 could be assessed through an assignment containing a task to determine resultant and relative velocities in a system of moving bodies and a task to determine the output motion of plain mechanisms for given input conditions. Both a slider-crank and four-bar chain should be considered, while a third task to achieve M3 could be to determine the output velocity of a quick-return mechanism. In all three criteria, there is an expectation that the response will involve the construction of diagrams to help determine the solution.

A final assignment for P6 and P7 should contain tasks to determine the parameters of simple harmonic motion for a system generated by uniform circular motion, a mass-spring system and a simple pendulum. These could be followed by a task to evaluate the output motion of a slider-crank mechanism for uniform input rotation of the crank to achieve merit criterion M4.
The evaluation should conclude that the motion is not simple harmonic but that it may be approached by lengthening the connecting link. A final task to achieve distinction criterion D2 could involve the gathering and analysis of test data to determine the contributory effect of spring mass on the periodic time of a vibrating mass-spring system. The test data may be given in the absence of practical test facilities.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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</thead>
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<tr>
<td>P1, M1</td>
<td>Uniaxial and Complex Loading</td>
<td>A suitable engineering situation to set problems involving engineering components subjected to uniaxial loading, 2D and 3D loading.</td>
<td>A written report containing an explanation to each step in the sequence of calculations, experiments or simulations and findings.</td>
</tr>
<tr>
<td>P2, P3, M2, D1</td>
<td>Bending and Torsion</td>
<td>A suitable engineering situation to set problems on a simply supported beam and problem on a power transmission shaft. Evaluation of load-carrying capacity and power-transmission capacity.</td>
<td>A written report containing an introductory explanation to each step in the sequence of calculations and findings. A written evaluation of the load-carrying capacity of a beam and the power-transmission capacity of a shaft.</td>
</tr>
<tr>
<td>P4, P5, M3</td>
<td>Resultant and Relative Velocity</td>
<td>A suitable engineering situation to set problems involving resultant and relative velocity of moving bodies and motion in plane mechanisms.</td>
<td>A written report containing an introductory explanation to each step in the sequence of graphics and calculations.</td>
</tr>
</tbody>
</table>
### Essential resources

Centres should have access to investigation and demonstration equipment, such as simply supported beam apparatus, torsion test apparatus and apparatus for the investigation of simple harmonic motion.

### Indicative reading for learners

**Textbooks**


Unit 24: Engineering Primary Forming Processes

Level: 3  
Unit type: Optional  
Assessment type: Internal  
Guided learning: 60

Unit introduction

Almost everything we touch in the world of technology has been created through some technique or process associated with primary forming – the forming of shapes with minimal waste and loss of volume. Without these primary forming processes, the technological world as we know it today would not exist.

Many engineering components are initially formed by moulding, deformation or shaping. Over the years, these processes have been refined to suit the introduction of new materials and the demands of quantity production. In some processes, the shaped component is almost ready for use and requires only a little cleaning and trimming. In others it is produced slightly oversize and, after cleaning and trimming, it is machined accurately to the required dimensions.

The main aim of this unit is to provide a broad understanding of manufacturing processes associated with primary forming. It will give learners a broad understanding of moulding techniques for metals, ceramics and polymers, deformation processes for metals and polymers, and shaping and assembly of composites. The unit will introduce learners to a range of techniques and primary processes but will provide a deeper understanding of the more common processes.

For each technique and process, learners will form an appreciation of the fundamental process requirements, the working techniques used and the relevant health and safety considerations. The use of these primary processes sometimes creates a dangerous environment and knowledge of relevant health and safety and related legislation is very important.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand how moulding techniques involving metals, ceramics and polymers are used
2. Understand how deformation processes involving metals and polymers are used
3. Understand how shaping and assembly processes involving composites are used
4. Understand how health and safety issues relate to primary forming processes.
Unit content

1 Understand how moulding techniques involving metals, ceramics and polymers are used

Moulding techniques involving metals: casting method, e.g. sand, die (gravity, pressure), investment, continuous; metal applicable to process, e.g. ferrous (carbon steels, stainless steels, cast iron), non-ferrous (aluminium, copper, brass, zinc, magnesium, nickel, titanium, alloys); form of material supply, e.g. pig iron, scrap, ore, ingots, recycled material, metal composition, trace elements, coke, limestone; mould production, e.g. patterns, cores, dies, moulding parts (boxes, sand, reinforcements, releasing agents, runners, risers, sprues); component removal and finishing, e.g. knock out, ejection, fettling

Moulding techniques involving ceramics: powder metallurgy (blending, compacting); sintering; secondary operations, e.g. infiltration, sizing, coining, machining, impregnation, plating, heat treatment; ceramics applicable to process, e.g. metallic carbides, nitrides, oxides

Moulding techniques involving polymers: techniques e.g. compression, transfer, injection, rotational moulding, blow moulding; polymers applicable to process, e.g. thermoplastics, thermosetting plastics, polystyrene, polyethylene, acetal, acrylonitrile butadiene styrene (ABS), nylon, polycarbonate, polypropylene; use of additives, e.g. stabilisers, flame retardants, fillers (asbestos, cotton flock, fibres, mica, graphite, wood flour), plasticisers, antistats, colorants, lubricants; mould tools, e.g. two plate, three plate, combination/composite, split, unscrewing; moulding parameters, e.g. temperature, pressure, speed/timings, distance, flashing, short shot, distortion, burning, colour deviation

2 Understand how deformation processes involving metals and polymers are used

Deformation processes involving metals: processes, e.g. extrusion (direct, indirect, impact), forging (drop, pressure, upset), rolling (hot, cold), presswork (forming, bending, deep drawing), metal spinning; metals applicable to process, e.g. ferrous (carbon steels, stainless steels), non-ferrous (aluminium, copper, brass)

Deformation processes involving polymers: processes, e.g. vacuum forming, extrusion, calendaring; polymers applicable to process, e.g. thermoplastics, polycarbonate, polysulphon, acrylic, polyvinyl chloride, ABS, thermoplastic sheet; use of additives, e.g. plasticisers, antistats, lubricants, heat stabilisers; features, e.g. double curvatures, shapes (male, female), stiffened mouldings, section shape; parameters, e.g. temperature, pressure, speed/timings, distance, flashing, short shot, distortion, burning, colour deviation
3 Understand how shaping and assembly processes involving composites are used

Composite shaping processes: processes, e.g. pre-preg laminating, wet lay-up, moulding; use of fibre (glass, polyethylene, aramid, carbon); use of resin (polyester, vinyl ester, epoxy, phenolic); composite materials applicable to process, e.g. wood, Coremat, foam, honeycomb (Nomex, aluminium), syntactic core, expanding core; design features, e.g. corners (internal, external), surface (concave, convex, return, vertical), double curvature, nett edges, joggle details; types of reinforcement e.g. roving, braids, tapes, chopped strand, continuous filament, uni-directional, woven, multi-axis

Composite assembly processes: types, e.g. trial, one-off, batch, assembly line; features e.g. tolerances (loose or close fit), fixing (permanent or non-permanent), shape location, joins (joggle, return or overlap); assembly methods, e.g. fettling, pinning, clamping, trial fitting, aligning, assembly jigs and sequences; joining methods e.g. thread inserts, fasteners (mechanical, quick release), anchor nuts, rivets; composite components, e.g. trim, panels (closing, body), tubes, structural, aerodynamic, core materials, sections, inserts, housings; non-composite components, e.g. brackets, fixtures, fittings, trim, tapes, memory foam, films

4 Understand how health and safety issues relate to primary forming processes


Reducing risks: e.g. use of risk assessment methods, avoidance of dangerous conditions, appropriate training, good housekeeping, safe use of tools and equipment
## Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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</thead>
<tbody>
<tr>
<td><strong>P1</strong> explain the moulding techniques used to manufacture a metal-based component</td>
<td><strong>M1</strong> compare and contrast the different moulding techniques used to manufacture products from metals, ceramics and polymers</td>
<td><strong>D1</strong> justify the use of a specific moulding technique for the manufacture of a given product</td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong> explain the moulding techniques used to manufacture a ceramic-based component</td>
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<tr>
<td><strong>P3</strong> explain the moulding techniques used to manufacture a polymer-based component</td>
<td><strong>M2</strong> compare and contrast the different deformation processes used to manufacture products from metals and polymers</td>
<td><strong>D2</strong> justify the use of a deformation process for the manufacture of a given product.</td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> explain the deformation processes used to manufacture a metal-based component</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong> explain the deformation processes used to manufacture a polymer-based component</td>
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<tr>
<td><strong>P6</strong> explain the shaping processes used to manufacture a composite-based component</td>
<td><strong>M3</strong> explain why a composite shaping process is appropriate for a given manufactured product</td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> explain the methods used to manufacture a composite-based assembly</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> explain the health and safety issues that relate to each of the primary forming processes considered</td>
<td><strong>M4</strong> suggest improvements that could reduce the risk to the health and safety of a primary forming process operator.</td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> explain methods of reducing risk for each of the primary forming processes considered.</td>
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</table>
Essential guidance for tutors

Assessment

A suitable strategy for this unit would be for learners to carry out detailed investigations into the way given or chosen products are manufactured. A range of products will be required and needs investigated to ensure learners have opportunities to cover the range of primary forming processes listed and the requirements of the assessment criteria.

Criteria P1, P2, P3, M1 and D1 relate to learning outcome 1 and P4, P5, M2 and D2 relate to learning outcome 2. These could be assessed by the first two assignments. These assignments should give learners an opportunity to demonstrate their understanding of the different moulding techniques and deformation processes. The tasks set should ensure that they explain a moulding technique suitable for each of the materials covered by learning outcome 1 (i.e. metals, ceramics and polymers) and suitable deformation processes for both metals and polymers for learning outcome 2. Tasks set in the assignments could require learners to compare and contrast particular moulding techniques (M1) and deformation processes (M2) for products made from the materials listed in the content for learning outcomes 1 and 2 respectively. For the products selected, learners must justify the moulding technique used (D1) and deformation process (D2).

A third assignment could concentrate on composite manufacture (learning outcome 3). A task should be set to explain both a composite shaping process (P6) and a composite assembly process (P7). A further task, or a holistic task, could then ask learners to explain why a particular composite shaping process would be appropriate for a given manufactured product (M3). Care should be taken when selecting a product for this task to ensure that it has all the requirements of the content within the learning outcome, i.e. the use of fibre, resin, design features and types of reinforcement. Likewise, the explanation for P6 should also have these aspects of content covered.

The final assignment should enable learners to achieve P8, P9 and M4. They should be asked to explain the health and safety issues that relate to the processes covered earlier (P8) and to describe risk reduction for one process (P9).

To cover M4, learners could evaluate and suggest improvements to any relevant aspects of legislation or risk within an area of interest to them (for example use of equipment, guards, clothing and handling). The most important aspect of the evidence will be learners’ ability to evaluate the situation and come up with some distinct and valid improvements.

The assessment evidence for this unit is likely to be in the form of a number of written responses in a portfolio that may include information and diagrams. Centres need to take care that the evidence used for assessment is learners’ own work and that where learners make use of other people’s work then this is clearly acknowledged and referenced. Centres may find it helpful to guide learners by providing a recommended structure for their descriptions and in particular a format/system for including references.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, P2, P3, M1, D1</td>
<td>Moulding Techniques for Metals, Polymers and Ceramics</td>
<td>An activity requiring learners to carry out research based on actual engineering techniques and suitable roles associated with metals, polymers and ceramics.</td>
<td>A portfolio containing written responses and diagrams showing moulding techniques for each material family type. Carried out under controlled conditions. This activity could be supported by a PowerPoint presentation.</td>
</tr>
<tr>
<td>P4, P5, M2, D2</td>
<td>Deformation Processes for Metals and Polymers</td>
<td>An activity to investigate, aligned to a suitable role, the processes associated with the deformation of a range of metals and polymers.</td>
<td>A portfolio containing written responses and diagrams showing deformation processes for metals and polymers. Carried out under controlled conditions. This activity could be supported by a PowerPoint presentation.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
<td>Scenario</td>
<td>Assessment method</td>
</tr>
<tr>
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<tr>
<td>P6, P7, M3</td>
<td>Shaping and Assembling Composite-based Products</td>
<td>An activity to investigate the shaping and assembly processes associated with composite product manufacture set within a suitable context.</td>
<td>A portfolio containing written responses and diagrams showing composite shaping processes and assembly processes used to manufacture composite based products. Carried out under controlled conditions. This activity could be supported by a PowerPoint presentation.</td>
</tr>
<tr>
<td>P8, P9, M4</td>
<td>Improvements to Processes and Health and Safety in Primary Forming</td>
<td>An investigative activity based around a suitable role involving the review of the health and safety issues associated with primary forming processes involving metals, polymers and ceramics. Followed by a case study to improve the primary forming process of a manufactured product and making a safer environment for an operator.</td>
<td>A portfolio containing a written commentary about health and safety and risk reduction. This activity could be supported by an evaluation of a process to suggest improvements to the process and its safe operation. Evidence could also be made available by a PowerPoint presentation.</td>
</tr>
</tbody>
</table>
Essential resources

Centres must have access to a range of cast, ceramic-moulded, polymer-moulded and process-deformed components, along with a range of components made from composites, including both shaped and assembled. Ideally, centres would have facilities to practically demonstrate some of the primary processes covered by the unit content, although this is not essential. However, centres that are unable to do so should consider industry visits or, alternatively, video and other presentation resources. Access to relevant health and safety legislation will be required.

Indicative reading for learners

Textbooks


Health and Safety Executive – Health and Safety in Engineering Workshops (Health and Safety Executive, 2004) ISBN 9780717617173

Unit 25: Engineering Secondary and Finishing Techniques

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

For everyday products and components to be manufactured to a required standard, the machines that produce them need to be operated in an efficient and safe manner. During this process, trial components are made to check accuracy and ensure a minimum amount of waste during production. Machine operators will produce better components if they are aware of a range of finishing and secondary processes that can be used. A secondary process is where raw material or a component is taken for further working, usually involving material removal, and is carried out after a primary forming process.

This unit aims to give learners a detailed knowledge of the use of secondary processing machines, including traditional machines (for example lathes and drilling machines) and others found in a more specialist workshop (for example spark or wire erosion methods).

The unit gives learners an opportunity to examine a range of secondary processing machines, their design and application. To a lesser extent, they will also identify a range of ‘non-traditional’ techniques, such as electro discharge and broaching.

Learners will investigate heat treatment processes, which are often used to get a product or component into its final state and ready for use. Without these processes parts would fail prematurely or further manipulation would not be possible on certain materials to create a final component. Learners will also understand assembly methods, including automated techniques that can be associated with computer-aided manufacture and other modern approaches, such as flexible manufacturing systems.

Finally, learners will understand how finishing techniques are used in engineering to add either function or aesthetics to a part component or product. Anodising and plating methods will be discussed, as well as hot processes used to obtain a required finish (such as powder coating or hot dipping) and the associated aspects of health and safety.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand how a range of secondary machining techniques are used
2. Know how a range of non-traditional techniques are used
3. Know how heat treatment processes and assembly techniques are used
4. Know how finishing techniques are used.
Unit content

1 Understand how a range of secondary machining techniques are used

**Turning:** machine e.g. centre lathe, turret; features of the workpiece, e.g. flat faces, diameters (such as parallel, stepped, tapered), holes (such as drilled, bored, reamed), profile forms, threads (such as internal, external), eccentric features, parting off, chamfers, knurls or special finishes, grooves, undercuts

**Millling:** machine, e.g. horizontal, vertical, universal, planer/pantry; up-cut; down-cut; features of the workpiece, e.g. faces (such as flat, square, parallel, angular), steps/shoulders, slots (such as open ended, enclosed/recesses, tee), holes (such as drilled, bored), profile forms (such as vee, concave, convex, gear), serrations, indexed or rotated forms, special forms

**Boring:** machine, e.g. horizontal, vertical; features of the workpiece e.g. bored holes (such as through workpiece, to a depth, tapered), holes (such as drilled to depth, drilled through workpiece, reamed, threaded), external diameters, grooves/recesses, chamfers/radii, faces (such as flat, square, parallel, angular, milled), slots, forms (such as indexed, rotated), external tapers

**Grinding:** machine, e.g. surface (such as horizontal, vertical), cylindrical (such as external, internal), centreless, universal, thread, profile; features of the workpiece, e.g. faces (such as flat, vertical, parallel, square to each other, shoulders and faces), slots, diameters (such as parallel, tapered), bores (such as counterbores, tapered, parallel), profiles forms, thread forms (such as vee, right hand, single start, multistart, internal, external), angular faces

**Presswork:** machines, e.g. single action, multiple action; features of the workpiece e.g. blanking, notching, piercing, joggling, cropping/shearing, bending/forming, coiling/rolling, planishing/flattening, first draw, second draw, compound operations, cupping, embossing, coining

**Health and safety:** appropriate legislation and regulations e.g. Health and Safety at Work etc. Act 1974, Fire Precautions Act 1971, manual handling, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013, Provision and Use of Work Equipment Regulations (PUWER) 1998, Health and Safety (First Aid) Regulations 1981; use of personal protective equipment (PPE)

**Materials:** e.g. ferrous, non-ferrous, non-metallic, stainless, special alloys, deep drawing steels

**Kinematics:** machine tool design; generation and forming of shapes; six degrees of freedom

2 Know how a range of non-traditional techniques are used

**Electro discharge:** machines e.g. spark erosion, wire erosion; features of the workpiece e.g. holes, faces (such as flat, square, parallel, angular), forms (such as concave, convex, profile, square/rectangular), other features (such as threads, engraving, cavities, radii/arcs, slots)

**Broaching:** machines e.g. horizontal, vertical; features of the workpiece e.g. keyways, holes (such as flat sided, square, hexagonal, octagonal), splines, serrations, other special forms

**Honing and lapping:** machines e.g. honing (such as horizontal, vertical), lapping (such as rotary disc, reciprocating); features of the workpiece e.g. holes (such as through, blind, tapered), faces (such as flat, parallel, angular)
3 Know how heat treatment processes and assembly techniques are used

*Heat treatment processes for ferrous metals:* surface hardening; other processes, e.g. hardening, tempering, annealing, normalising; appropriate health and safety requirements, e.g. Health and Safety at Work etc. Act 1974, requirements relating to chemicals and materials handling (such as Control of Substances Hazardous to Health (COSHH) Regulations 2002, safe disposal of waste materials and components (fluids, hardening materials), manual handling, safe use of electrical and pressurised equipment, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013, Provision and Use of Work Equipment Regulations (PUWER) 1998)

*Assembly techniques:* manual, e.g. screwed fasteners, locking devices, keys, dowels, circlips; automated, e.g. part feeding devices, transfer and indexing, orientation devices

4 Know how finishing techniques are used

*Hot processes:* e.g. hot dip treatment (such as molten wax, molten tin to steel, molten zinc to steel, organic coatings), powder coating (such as fluidised bed thermoplastic coating powder, fluidised bed thermosetting powder, electrostatic grade thermoplastic powder, electrostatic grade thermosetting powder)

*Anodising:* e.g. sulphuric acid, chromic acid, hard anodising

*Plating methods:* e.g. electroplating (such as copper, gold, silver, cadmium, platinum), electroless nickel, mechanical (such as mechanical zinc, mechanical tin-zinc, mechanical aluminium-zinc), alloy (such as brass, nickel-iron, tin-lead, zinc-nickel, zinc-iron, zinc-cobalt), zinc (such as cyanide zinc, alkaline zinc, acid zinc), nickel and chromium, hard chromium; substrates e.g. mild steel, stainless steel, brass, copper, zinc based, aluminium
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<th>Assessment and grading criteria</th>
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</tr>
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<tbody>
<tr>
<td><strong>P1</strong> explain how five different secondary machining techniques are used safely on a range of materials</td>
<td><strong>M1</strong> compare and contrast why different secondary machining techniques are used when manufacturing products</td>
<td><strong>D1</strong> evaluate the effective use of an appropriate secondary machining technique</td>
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</tr>
<tr>
<td><strong>P2</strong> explain kinematics in secondary machining techniques</td>
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<tr>
<td><strong>P3</strong> identify appropriate non-traditional techniques for six given products</td>
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<tr>
<td><strong>P4</strong> describe an appropriate non-traditional technique for a given product</td>
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<tr>
<td><strong>P5</strong> explain surface hardening and another heat treatment process for ferrous metals</td>
<td><strong>M2</strong> compare and contrast why different heat treatment processes are used when manufacturing products from ferrous metals</td>
<td></td>
<td></td>
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<tr>
<td><strong>P6</strong> describe two different manual and an automated assembly technique</td>
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<tr>
<td><strong>P7</strong> describe a hot process, anodising and plating method when used for finishing on different components</td>
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### Assessment and grading criteria

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<tr>
<td><strong>P8</strong> explain the appropriate heat treatment processes, secondary, finishing and assembly techniques needed to manufacture four given components.</td>
<td><strong>M3</strong> from given restrictions and information justify alternative assembly and finishing techniques.</td>
<td><strong>D2</strong> evaluate a given secondary machining technique and heat treatment process for health and safety risk and impact on the environment.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

It is important that the assessment strategies used are designed to suit the needs of learners. Good assessment strategies are most likely to be supported by proper presentation of appropriate evidence. A portfolio or file of evidence should not contain course notes, research etc. unless it is to become part of the required evidence and assessment.

Work done through the use of case-study material can be used to generate evidence for the portfolio, particularly if industrial visits are well embedded in delivery. It is likely that a range of products will need to be investigated to ensure learners have opportunities to cover the required range of secondary machining techniques and heat treatment processes, together with finishing and assembly techniques.

To achieve a pass, learners need to demonstrate understanding and knowledge of the different processes and techniques, explain or describe their characteristics and how they are used. While learners need to explain what is meant by kinematics in relation to secondary techniques, they only need to show enough knowledge to describe one non-traditional technique. However, they must select appropriate non-traditional techniques for six different products. Learners also need to describe both surface hardening and one of the other processes, such as annealing, and both types of assembly techniques (manual and automated). They should also describe all three types of finishing techniques as listed in the unit content.

This unit could be assessed through three assignments. The first assignment could be a series of written tasks to cover P1, P2, P3 and P4. The task for P1 should have enough detail for learners to cover turning, milling, boring, grinding and presswork. The types of machine they consider from each of these could be left to the learner, as they may have a preference from their place of work. Alternatively, a specific machine type could be given to different learners across the range. This would help centres authenticate each learner’s response.

The tasks should also ensure that learners consider the health and safety requirements and cover at least three of the material types listed in the content.

The six products given for P3 must cover the three non-traditional techniques ranged – electro discharge, broaching and honing/lapping. The products should have sensible characteristics, such as type of material, quantity, size, accuracy (tolerances) and surface texture requirements to clearly direct learners towards the correct non-traditional technique. The written task for P4 could be about one of the machines from these techniques. Again, some learners may have preferences based on their workplace. This assignment could also include further written tasks to cover both M1 and D1.

The second assignment could have tasks to explain heat treatment processes (P5) and assembly techniques (P6). Surface treatment must be covered but freedom can be given as to which other process is described. The task should also ask learners about the health and safety requirements. The task addressing P6 must cover two manual and one automated technique.

A further task could be developed to cover M2, which would give learners an opportunity to cover more of the range of heat treatment processes. A comparison between hardening, tempering and annealing would be sensible. Another task in the assignment could cover P7 ensuring that all finishing techniques are covered.
Another task should be given to allow learners to justify alternative assembly and finishing techniques (M3). In doing so, a range of restrictions and information should be given to ensure learners are able to come up with some sensible alternatives. An example is when the modification of an assembled component allows an automatic feeding device to be used, assuming the batch quantity information indicates it would be viable, or a material amendment needs a change of finishing technique.

The third assignment could have a task requiring learners to explain appropriate processes and techniques as listed in P8 for four different components. These components need to be fairly complex to include a requirement for a heat treatment process, a secondary, a finishing and an assembly technique. These requirements must not be given but be suggested by the component characteristics and specification. This can be done by a set of drawings/specifications or by actual products, with a set of notes that would ensure the learners are able to identify the appropriate process and techniques. A final written task could be included to give an opportunity to cover D2.

To achieve a merit, learners need to compare and explain how different machining techniques are used (M1) and how different heat treatment processes are used in manufacturing (M2). They will need to suggest alternative assembly and finishing techniques when given specific restrictions and information (M3).

To achieve a distinction, learners need to confidently evaluate the effective use of secondary machining techniques (D1) for certain circumstances. Learners should show skills in evaluating a given secondary machining technique and a given heat treatment process for health and safety risk and impact on environmental issues (D2).
## Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, P4, M1 and D1</td>
<td>Secondary and Non-traditional Machining Techniques</td>
<td>An activity requiring learners to carry out research based on actual secondary and non-traditional machining techniques associated with a range of materials.</td>
<td>A portfolio containing written responses and diagrams showing the five different secondary machining and non-traditional techniques for a range of material types, possibly supported by a PowerPoint presentation. Alternatively a case study could be used and presented as a portfolio.</td>
</tr>
<tr>
<td>P5, P6, P7, M2</td>
<td>Heat Treatment Processes, Assembly and Finishing Techniques</td>
<td>An activity to investigate the processes associated with the heat treatment of ferrous metals, and the use of hot processes and finishing techniques.</td>
<td>A portfolio containing written responses and diagrams showing heat treatment processes for ferrous metals and descriptions of assembly techniques, hot processes, anodising and a plating method. This activity could be supported by a PowerPoint presentation.</td>
</tr>
</tbody>
</table>
### Criteria covered

<table>
<thead>
<tr>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P8, M3 and D2</td>
<td>Secondary Processes and Finishing Techniques Associated with Manufacturing Products</td>
<td>An activity to investigate the heat treatment processes, secondary, finishing and assembly techniques associated with product manufacture.</td>
</tr>
</tbody>
</table>

### Essential resources

Centres should have access to as large a range of the machinery and processes outlined in the unit content as possible.

### Indicative reading for learners

#### Textbooks

- Health and Safety Executive – *Health and Safety in Engineering Workshops*  
  (Health and Safety Executive, 2004) ISBN 0717617173
Unit 26: Fabrication Processes and Technology

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Fabrication processes and technology are used in the production of metal structures in a wide range of manufacturing industries. The fabrication of metal structures involves four essential stages: measuring and marking out, preparation of the material for fabrication, forming processes and the assembly of the materials.

This unit gives learners with no previous fabrication experience an understanding of the processes and technologies used throughout the fabrication industry, whilst learning to work in a safe environment. The unit is appropriate for work-based learners or for those who are being prepared for employment in an industrial environment where fabrication is an integral part of the manufacturing process.

Learners will work with ferrous or non-ferrous metals in the form of sheet, plate and sectional materials to construct a fabricated structure. They will learn how to use a range of industrial hand tools and machinery to complete fabrication tasks. The unit will give learners the ability to identify the correct processes and equipment to use, and the tools and equipment appropriate to each stage of the fabrication process.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Understand health and safety legislation, regulations and safe working practices for fabrication activities
2. Know the processes used to mark out and prepare materials to produce fabricated structures
3. Know how materials are formed and assembled to produce fabricated structures
4. Be able to interpret the specification of a fabricated structure and plan and carry out its manufacture.
Unit content

1 **Understand health and safety legislation, regulations and safe working practices for fabrication activities**


*Safe working practices*: safety in the workshop and on-site; fire prevention; accident prevention and reporting; risk assessment; manual handling; checking conditions, e.g. gas leaks, voltage and amperage, correct fuses, leads, guarding of machinery and power tools; action to be taken when machinery and equipment are dangerous or in poor condition; personal protective equipment (PPE); ventilation and extraction; closing down, e.g. equipment safety, storing equipment, safe disposal of waste materials, use of compressed air

2 **Know the processes used to mark out and prepare materials to produce fabricated structures**

*Marking out*: measuring and marking out equipment, e.g. rule, protractor, tee square, set square, tape measure, compass, dividers, trammel, templates, marker pen, scriber, chalk line, laser level; detailed drawing, e.g. dimensions, tolerances; reference points, e.g. datum line, centre line datum; setting out, e.g. radial line, triangulation, projection, true lengths; calculations, e.g. bend allowance, allowance for springback, intersection points, overlap; calibration of equipment

*Fabricated structures*: examples from local industry; made in a centre’s workshop, e.g. equipment storage systems (i.e. tool rack, tool box), work bench, car maintenance equipment (i.e. axle stand, ramp, crawler board), ventilation ducting (i.e. collector hood, reducing section, tee connector)

*Preparing materials*: obtaining materials, e.g. sheet, bar, plate, section; standard bought out condition, e.g. hot-rolled, cold rolled, standard dimensions, profiles, thickness; metallic materials, e.g. ferrous, non-ferrous; cutting to size and shape, e.g. flame, plasma, powder, water jet, laser, band saw, hacksaw, reciprocating saw; shearing, e.g. hand, bench, rotary, reciprocating; guillotining, e.g. bench, power; nibbling, e.g. hand, power; presswork, e.g. piercing, blanking, punching; material removal, e.g. chiselling, drilling, trepanning, filing, grinding; automated methods, e.g. numerical control (NC), computer numerical control (CNC), direct numerical control (DNC), mechanical copying using templates
3 Know how materials are formed and assembled to produce fabricated structures

*Forming:* principles, e.g. spring back, bend allowance; forming by hand, e.g. hammer and former, fly press, bench mounted bending machine; forming by machine, e.g. folding machine, press brake; rolling tools (e.g. rolling rolls, pyramid rolls, slip rolls, cone rolls), angle ring-bending; swaging; deep drawing and pressing; web stiffeners; edge preparation; pipe bending; use of templates and patterns; automated methods, e.g. numerical control (NC), computer numerical control (CNC), direct numerical control (DNC)

*Fabricated structures:* examples from local industry; made in a centre’s workshop, e.g. equipment storage (i.e. tool rack, tool box), work bench, car maintenance equipment (i.e. axle stand, ramp, crawler board), ventilation ducting (i.e. collector hood, reducing section, tee connector)

*Assembly:* trial assembly or ‘physical mock up’, e.g. offering up, alignment, clamping, dimensional checks, adjustment, modification; workshop clamps, e.g. mitre joint, toggle, G clamp, rivet clamps/skin pins, magnetic clamping devices; joining methods, e.g. spot welding, continuous welding, laser welding, brazing, soldering, structural adhesives, riveting; mechanical fixings, e.g. nuts, bolts, screws, clamps, pipe connectors; web stiffeners; inspect and check against specification

4 Be able to interpret the specification of a fabricated structure and plan and carry out its manufacture

*Structure specification:* engineering drawing, e.g. assembly, detailed, development; material, e.g. steel, aluminium; material supply forms, e.g. plate of appropriate thickness, hollow section, solid section, pipe, tube; reference points, e.g. edge datum, centre line datum; dimensions, e.g. overall, reference, installation, tolerance; permanent and non-permanent assembly methods, e.g. thermal, adhesive, riveting, mechanical fixings; finish, e.g. paint, polymer coat, electro-plate, polish; quantity, e.g. one-off, small batch, large volume

*Plan and manufacture:* calculations, e.g. bend allowance, allowance for springback, intersection points, quantity of material required, minimisation of waste material; select suitable equipment, e.g. marking out, preparation, templates, patterns, forming and assembly; mark out; produce manufacturing aids, e.g. formers, jigs, templates; prepare and form individual parts of the assembly, e.g. cutting to size, edge preparation, piercing, bending; assemble the fabrication and join parts together, e.g. trial assembly or ‘physical mock up’, modification, weld, braze, rivet, fixings; meet the required accuracy as specified, e.g. dimensions, tolerances, finish, visual appearance, joint quality; inspect and check against specification
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tbody>
<tr>
<td>P1</td>
<td>explain the key features of the health and safety legislation, regulations and safe working practices applicable in a fabrication workshop</td>
<td>M1 explain the effect, including aspects of safety and quality, of using incorrect equipment and processes to produce a fabricated structure</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>describe the process of marking out when producing fabricated structures</td>
<td>M2 explain the factors that influence the assembly methods used in the production of a fabricated structure</td>
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</tr>
<tr>
<td>P3</td>
<td>describe the process of materials preparation when producing fabricated structures</td>
<td>D1 justify the methods used to prepare materials when producing a fabricated structure</td>
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</tr>
<tr>
<td>P4</td>
<td>describe how materials are formed before they are assembled into a fabricated structure</td>
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<tr>
<td>P5</td>
<td>describe the assembly process for a given fabricated structure</td>
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<td></td>
</tr>
<tr>
<td>P6</td>
<td>interpret the specification of a fabricated structure to plan its manufacture.</td>
<td>M3 produce a fabricated structure to specification.</td>
<td>D2 evaluate the quality of manufacture against that specified for a fabricated structure.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment of this unit could be achieved through the use of four assignments.

The first assignment could cover P1, with learners being asked to produce a written report. Evidence presented for P1 must be specific to fabrication processes and learners will need to be given clear guidelines about what to present. There is a huge amount of generic material that learners will have access to. Care should be taken to ensure that what they present is referenced properly and not directly copied from the internet or any other source. Grading criteria P1 and M1 complement each other and it may be that centres wish to cover them both in the first assignment. However, learners might do better if M1 is assessed later once they have a better understanding of the problems associated with using the wrong equipment and processes. If this is the case then M1 could be assessed through the assignment which addresses grading criterion P5.

P2, P3, M2 and D1 can be assessed through a second assignment. Evidence could be in the form of a written report supported by drawings, diagrams and photographic images of formative practical work carried out by learners as they investigated the various marking out and materials preparation techniques. Records of responses to oral questioning by the tutor may also be appropriate. Learners’ evidence should also demonstrate further understanding of what influences the use of assembly methods for M2. D1 requires learners to demonstrate an understanding of the techniques used to prepare materials for fabrication by justifying the use of a selected method.

A third assignment could cover P4 and P5 (and M1 if not already covered in the first assignment). This should follow a similar format as assignment 2, with much of the evidence being based on the practical investigations carried out by learners on forming and assembly techniques. If M1 is covered in this assignment, learners’ reports/evidence will also need to evidence their understanding of the consequences of using incorrect equipment and processes.

In P6 and M3, learners will use a given specification to plan and produce a fabricated structure. Care should be taken when designing the assignment brief for P6 and M3 to make sure that it does not just become a test of the learners’ practical skills. Due to the time constraints of delivering the unit, it is not reasonable to expect learners to carry out joining processes that require a higher level of skill at an expert level.

There is scope to assess learning outcome 4 as a group activity so that learners can appreciate working as a team to produce a larger fabrication. Each learner could be given a part to work on, although care needs to be taken to ensure that the evidence presented by each learner addresses the whole of the unit content and can be substantiated. Digital annotated photographic images together with witness statements and observation records should be used to consolidate learner evidence of practical competence.

To achieve D2, learners could evaluate the quality of the fabricated structure produced in M3 and report on the quality of the structure compared to that set out in the given specification. This offers an opportunity for learners to evaluate the preparation, forming and assembly techniques they have used and identify where they can develop skills and techniques to improve quality.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, M1</td>
<td>Health and Safety for Fabrication Activities</td>
<td>An activity-based assignment that requires learners to research and identify health and safety legislation and safe working practices in fabrication activities.</td>
<td>A report that outlines legislation and safe working practices applicable to fabrication activities. The report should identify and clearly reference all research materials.</td>
</tr>
<tr>
<td>P2, P3, M2, D1</td>
<td>Marking Out and Preparing Fabrication Materials</td>
<td>A written assignment that evidences and further investigates the formative practical tasks that have been carried out in a fabrication workshop.</td>
<td>A written report will form a summative assessment that contains drawings, diagrams and photographs to evidence the range of marking out and preparation processes. Learners will justify the methods they have used to prepare materials in a fabrication workshop.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
<td>Scenario</td>
<td>Assessment method</td>
</tr>
<tr>
<td>------------------</td>
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</tr>
<tr>
<td>P4, P5</td>
<td>Forming and Assembling Fabrication Materials</td>
<td>A written assignment that evidences the practical investigations that the learner has carried out in a fabrication workshop.</td>
<td>Summative assessment will require a written report that contains evidence of the range of forming and assembly processes used in a fabrication workshop. The report will be supported with diagrams and photographs of their work. The report will examine the possible effects of using incorrect tools and processes. It will also include learners’ interpretation of why particular assembly processes have been used.</td>
</tr>
</tbody>
</table>
### Criteria covered
P6, M3, D2

### Assignment title
Manufacturing From a Specification

### Scenario
A practical assignment that requires the learner to plan and make a fabricated structure from a given specification.

### Assessment method
Learners will interpret information from a given specification and produce a plan of the processes and fabrication techniques to be used.

Having planned the work, and agreed the plan with the tutor, learners will produce the fabricated structure given in the specification.

Learners will produce a report which evaluates the quality of their work against the original specification.

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### Essential resources
Learners will need access to workshop facilities equipped with a range of marking out, forming and assembly tools and equipment, along with a variety of fabrication materials. Access to current health and safety legislation and regulations would also be useful for learning outcome 1.

### Indicative reading for learners

**Textbooks**

Unit 27: Welding Technology

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

A diverse range of welding processes is used in the manufacturing engineering industry, including manual, mechanised and machine-based techniques. The selection and application of these joining processes is vital in terms of the weld quality, and the economic viability of the finished product.

Learners will appreciate the need to produce high-quality welded joints in components based on the selection of the most appropriate process. To enable learners to make an informed choice, they will be required to select joining processes to satisfy a given application. The unit is appropriate for work-based learners where their industrial environment utilises welding as an integral part of the manufacturing process. It is also suited to learners who are being prepared for employment in the welding industry.

Learners will perform a range of formative practical tasks that will include planning and preparing for work and ensuring that health and safety legislation and safe working practices are understood and followed at all times. Learners will select and check the condition of appropriate equipment, which is particularly important considering that learners could be working with electric currents, combustible gas mixtures or parts rotating at high speed.

Continuous formative assessment allows learners to develop their practical skills and knowledge, which lead to summative assessments. Assignments will require them to report and record the development of their skills in the preparation and production of welded joints. Learners will inspect their work with reference to relevant quality standards, ensuring that they are capable of producing welded joints and are able to recognise defects.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand health and safety legislation, regulations and safe working practices in the welding industry
2. Be able to prepare for welding operations
3. Be able to produce welded joints to a quality standard
4. Understand how quality inspection processes are applied to welded joints in components.
Unit content

1 **Understand health and safety legislation, regulations and safe working practices in the welding industry**


*Safe working practices:* fire prevention; accident prevention and reporting; risk assessment; manual handling, e.g. materials, safe handling of gas cylinders; checking conditions, e.g. gas leaks, voltage and amperage, correct fuses, circuit breakers, leads, earthing of equipment; personal protective equipment (PPE); ventilation and extraction; closing down, e.g. equipment safety, storing equipment, safe disposal of waste materials; emergency procedures, e.g. within the learning environment and the workplace; hazards associated with welding, e.g. burns, electric shock, radiation

2 **Be able to prepare for welding operations**

*Information sources:* safety instructions; job instructions; engineering drawings; quality control documentation, e.g. weld procedure specification (WPS), record and reporting sheets

*Tools and equipment:* check equipment availability; function and condition relevant to the welding process, e.g. cables, hoses, torches and electrode holders, gas pressure regulators, flow meters; working environment, e.g. workshop, site work, conditions for machinery and plant; assembling welding equipment, e.g. cables, weld return clamps, electrode holders, gas cylinders, regulators, valves, safety devices

*Welding parameters:* setting and adjusting, e.g.:

- for manual processes: gas pressure, flow rates, voltage, current (either alternating (AC) or direct (DC)), according to electrode or filler size
- for mechanised processes: safety devices, welding speed, other parameters (electrical parameters, flux dispensing and recovery mechanisms, wire feed rate, filler diameter, gas shielding system, mechanical functions (handling, loading, work holding, transfer))
- for resistance welding machines: welding current, welding and squeeze times, electrode pressure cycle, electrode size, welding speed (seam), weld pitch (spot), mechanical functions, electrode diameter and condition
- for laser welding machines: electrical parameters, welding speed, weld alignment and characteristics, beam tracking, beam characteristics (focal spot), gas shielding, mechanical mechanisms for work holding, traversing and transfer
• for friction welding machines: friction and forge cycle time, friction and forge loads (forces), rotational speed or other friction conditions (orbital, frictional burn-off characteristics, forge displacement, braking effort), weld appearance (correct upset)

_Welding processes:_ manual, e.g. manual metal-arc (MMA), metal inert gas (MIG), metal active gas (MAG), metal-arc gas shielded, flux cored wire, tungsten inert gas (TIG), plasma-arc, gas welding; mechanised, e.g. MIG/MAG, cored wire, TIG, plasma-arc, submerged arc; machine based, e.g. resistance welding machines (spot, seam, projection), laser welding machines, friction welding machines

_Constructables:_ appropriate to process, e.g. electrode (rutile, basic, nickel alloy, cellulosic, stainless steel, other electrodes), filler wire, gases (oxygen, acetylene, shielding gases), inert and active gases, flux/agglomerated flux, forms of supply, care when handling flux; safe storage of consumables

3 **Be able to produce welded joints to a quality standard**

_Safety:_ fire prevention; accident prevention and reporting; using risk assessment; manual handling; equipment maintenance; checking conditions, e.g. gas leaks, voltage and amperage, fuses, circuit breakers, leads; wearing PPE; fumes; using ventilation and extraction; closing down equipment safely after use

_Joints/components:_ e.g.

• for manual processes: butt, fillet, autogenous weld (without filler wire)

• for mechanised processes: two different joint configurations, two different material groups

• for resistance welding machines: two different material thicknesses, two different joint configurations

• for laser and friction welding machines: two different components, two different material groups

_Welding positions:_ to a relevant standard, e.g. British Standard (BS) EN 287 flat (PA), horizontal vertical (PB), horizontal (PC), vertical upwards (PF), vertical downwards (PG), overhead (PE), inclined tube/pipe (H-L045 or J-L045); welding technique e.g. torch angle, filler angle

_Material:_ forms e.g. plate (thickness appropriate to process, up to 6 mm for resistance welding), section, pipe/tube, sheet (< 3 mm), other forms; types, e.g. carbon steel, stainless steel, aluminium

_Quality standard:_ minimum weld quality standard equivalent to the level given in the relevant standard, e.g. European/International Standard BS EN ISO 5817, BS EN ISO 10042, BS EN ISO 13919-2; meet the required accuracy as specified, e.g. dimensions, tolerances, weld quality, spot and projection welds are correctly located
4 Understand how quality inspection processes are applied to welded joints in components

Quality standard: safety in the use of test equipment and chemicals; minimum weld quality standard equivalent to the level given in the relevant standard, e.g. European and International Standard BS EN ISO 5817, BS EN ISO 10042, BS EN ISO 13919-2, BS EN 12062; meet the required accuracy as specified e.g. dimensions, tolerances, weld quality, spot and projection welds are correctly located

Testing: non-destructive inspection, e.g. dye penetrant, ultrasonic, radiographic (x-ray, gamma ray), pressure tests (hydraulic, pneumatic), fluorescent particle, magnetic particle; destructive e.g. macroscopic examination, nick break (fracture) tests, bend tests visual inspection; weld gauges, e.g. fillet, leg length, undercut and hi-lo gauges
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td>P1 explain aspects of health and safety legislation, regulations and safe working practices applicable to welding</td>
</tr>
<tr>
<td>P2 use information sources to select a welding process for a given application, and suggest suitable parameters for the welding process</td>
</tr>
<tr>
<td>P3 produce a list of consumables that are required for a selected welding process</td>
</tr>
<tr>
<td>P4 plan the tools and equipment needed to produce welded components safely, using a selected welding process</td>
</tr>
</tbody>
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## Assessment and grading criteria

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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P5</strong> use appropriate welding positions and materials to produce two welded joints safely with a manual or mechanised welding process</td>
<td><strong>M3</strong> discuss the advantages and disadvantages of two welding processes considering consumables, equipment, technique and quality for a given welding application</td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> produce two welded joints/components to a quality standard using a manual or mechanised welding process</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> use appropriate welding positions and materials to produce two welded joints safely with a machine-based welding process</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> produce two welded joints/components to a quality standard using a machine-based welding process</td>
<td></td>
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</tr>
<tr>
<td><strong>P9</strong> explain the results of a destructive and non-destructive test on a given joint/component when welded to a quality standard.</td>
<td><strong>M4</strong> explain the benefits and limitations of using a non-destructive inspection methods on welded components.</td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment of this unit could be through the use of four assignments.

The first assignment could cover P1 where learners are asked to produce a written report. Evidence for P1 must be specific to welding and the processes used within the industry. Learners will need clear guidelines in respect of what they should present. There is a large amount of generic material that learners will need to access. Care should be taken to ensure that what is presented is properly referenced and not directly copied from the internet or any other source.

A second assignment covering P2, M1 and D1 could be used to demonstrate the information sources to select a welding process. The practical experience will influence learners’ ability to answer this task. M1 and D1 can be achieved by analysing the effect of incorrect welding parameters and justifying a selected process for a given welding application. Learners will need to demonstrate their knowledge of both joining processes and the properties of engineering materials.

A third assignment covering P3, P4, M2 and D2 could be used to demonstrate the preparatory requirements for a selected welding process. Evidence could be presented in the form of a written report or by an oral presentation, supported by diagrams and photographs of formative practical work. Learners will need to select and describe a welding process for a given application. The expectation within this task is that all areas of the process will be described and the stated quality standards will be taken into account. M2 and D2 could be achieved with reference to safety and quality standards, as shown in the content, associated with the welding process.

Criteria P5, P6, P7, P8 and M3 could be assessed through a fourth practical assignment. The evidence for the practical investigations will be in a written report format, or may be assessed as part of a logbook or portfolio that records the types of joint, materials and positions used, and the consumables required for the process. This may be supported by witness statements or observation records used to show the evidence required. This will provide evidence of the joints produced using either a manual or mechanised welding process. The choice of whether a manual or mechanised process should be used is left to the centre and may be decided by the pathway that learners are following in their workplace. More freedom of choice may exist with centre-based learners but attention should be given to likely local employment opportunities. Criteria P7 and P8 require joints to be welded using machine-based processes which should be assessed in a similar format to P5 and P6. Care must be taken to consult the content section of the unit to ensure that the range of welding positions, joints, materials and consumables appropriate to the joining process being assessed for the manual, mechanised and machine-based welding processes. M3 can be achieved by learners comparing two processes, which could be the processes used in P6 and P8, and demonstrating further knowledge of the processes. Care will be required when selecting the given application to ensure learners have opportunities to carry out this comparison. Although it is not compulsory to have a manual and mechanised process, this is where opportunities may be maximised during a comparison.
A fifth assignment could be used in assessing P9 and M4, where learners use a report to explain the results of quality standards used for the joints produced in P6 and P8. Learners should include their findings, and refer to the standards, accuracy, destructive and non-destructive tests used. Reference should be made to the original guidelines for the given application and any quality standards that are indicated. This will enable them to explain the benefits and limitations of non-destructive inspection methods (M4).
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Safe Working Practices When Welding</td>
<td>Learners need to produce an information report on health and safety requirements and safe working practices applicable to the welding industry.</td>
<td>A written report that explains the legislation and safe working practices used in the welding industry, with clear referencing to appropriate sources of information.</td>
</tr>
<tr>
<td>P2, M1, D1</td>
<td>Using Information</td>
<td>Learners have to select a suitable process and welding parameters and identify consumables</td>
<td>A written report could be used to assess the pass criteria using diagrams and photographs of relevant information. Further analysis and justification would assess M1 and D1. It may be considered that an oral presentation, supported with appropriate graphics, may be more suitable in the assessment of all criteria in this assignment. The tutor should consider the method of maintaining evidence of the presentation.</td>
</tr>
<tr>
<td>P3, P4, M2, D2</td>
<td>Preparing for Work</td>
<td>Plan the consumables, tools and equipment needed for a given welding application (e.g. a number of welded joints to form a simple component).</td>
<td>A written report supported by a logbook or portfolio that records the range of consumables, tools and equipment.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
<td>Scenario</td>
<td>Assessment method</td>
</tr>
<tr>
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<td>-------------------</td>
</tr>
<tr>
<td>P5, P6, P7, P8, M3</td>
<td>Producing Quality Welded Joints</td>
<td>Learners need to produce welded joints to a required quality standard.</td>
<td>A written report supported by a logbook or portfolio that records the range of joints, materials and welding positions used. Evidence of the weld quality may include photographs, diagrams, witness statements, and quality reports. The report should identify the quality standards used and compliance to that standard. A comparison of two welding processes clearly identifying the processes and the advantages and disadvantages of each process for a given application should be included.</td>
</tr>
<tr>
<td>P9, M4</td>
<td>Inspecting Welded Joints</td>
<td>Learners test welded joints that they have previously made in a material or component.</td>
<td>A practical activity evidenced by a report that discusses the quality inspection processes used for the joints produced in P6 and P8 and the results. The report can further investigate the benefits and limitations of using non-destructive testing techniques on welded components.</td>
</tr>
</tbody>
</table>
**Essential resources**

Centres delivering this unit will need access to appropriate welding equipment, consumables and materials as outlined in the unit. Centres must also have access to appropriate destructive and non-destructive test equipment.

**Indicative reading for learners**

**Textbooks**


Unit 28: Selecting and Using Programmable Controllers

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

The automation of machines, process control and conveyor lines has resulted in the ever-increasing consistency of quality, speed and cost savings in complex processes. Consumers have come to expect high standards of quality in the manufactured goods they use, but to an engineer these are the challenges that make the profession interesting.

This unit will consider programmable logic controllers (PLCs), control devices which aid the automation of these processes. The capabilities of PLCs have developed over the years, with performance, reliability and operational resilience being key attributes to their continued success. In order to achieve automated monitoring and control, these devices can be used on their own or in conjunction with others through communication systems/links, which are themselves becoming more versatile.

The unit will introduce learners to the use and applications of PLCs, the hardware and software that makes up a PLC and the interaction needed between the component parts. Learners will develop their ability to use programming techniques to produce programs for modern PLCs. They will gain an understanding of the different types of communication media used to link larger numbers of PLCs together, the networking architecture used and the associated standards and protocols.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand the selection, hardware and software requirements of a programmable controller
2. Be able to use programming techniques to produce a program for a modern programmable controller
3. Understand complex programmable controller applications
4. Understand data communications media and networks used with modern programmable controllers.
Unit content

1 Understand the selection, hardware and software requirements of a programmable controller

**Programmable controller selection:** types (unitary, modular, rack-mounted); criteria, e.g. cost, versatility and scanning time; internal architecture, e.g. central processing unit (CPU), arithmetic and logic unit (ALU), flags, registers, memory and types (volatile, non-volatile); scan cycle (self-test, input/logic/output scans)

**System hardware and software requirements:** manufacturers’ specification of input/output (I/O) units (digital and analogue); power supply; use of operating system; configuration of inputs and outputs; number systems, e.g. binary, octal, hexadecimal, binary-coded decimal (BCD); input/output devices; mechanical switch relays (electromechanical and solid state); transducers, e.g. temperature, pressure, flow, smart sensors, simple motors and drives

2 Be able to use programming techniques to produce a program for a modern programmable controller

**Programming techniques:** e.g. ladder and logic diagrams, statement listing, functional diagrams, graphical programming languages, mimic diagrams, sequential function charts (SFCs)

**Produce, store and present program:** human-computer interface (HCI), e.g. handheld input pad, personal computer, text, graphical touch screens; use of system software to write, edit, delete, save, restore, create reports, load/unload, search; use of fault diagnostic indicators; print copies of program; storage, e.g. scanning, memory organisation, continuous updating, back-up copies, supervisor control and data acquisition (SCADA)

**Instruction types:** production of program using relay, bit, branch, timer/counter, comparison, logical, arithmetic instructions; proportional integral derivative (PID) controller loops

3 Understand complex programmable controller applications

**Program documentation:** hardware considerations (environmental, operational, maintainability); instruction types; documentation for testing, e.g. software debug instructions, diagnostic indicators, data monitors, search, force facilities; complex engineering applications, e.g. machine, process control, conveyor

**Health and safety with programmable controller:** safe working practices for personnel and with equipment, e.g. tools and equipment risk assessment, job safety analysis (JSA), housekeeping practices for work areas, personal protective equipment (PPE), restriction of non-participants from areas; health and safety standards (local, national, international), e.g. local safety agreements between employees and employers, Health and Safety Executive (HSE), Health and Safety at Work etc. Act 1974, regulations for the use of display screens; avoiding haphazard operations, e.g. risk management, planning considerations, testing (usability, unit, component, acceptance), ‘what if’ scenarios, commissioning
4 Understand data communications media and networks used with modern programmable controllers

*Communication media:* selection criteria, description of features, frequency ranges, technology, e.g. analogue, digital, wireless; cable, e.g. twisted pairs, coaxial, fibre-optic, shielded/unshielded, categories, operational lengths; connector, e.g. Bayonet-Neill-Concelman (BNC), registered jack (RJ-45), straight tip (ST), universal serial bus (USB) type A and type B; opto-isolator e.g. photodiode, phototransistor, thyristors, triacs

*Network:* network architecture (fieldbus, distributed intelligence, ‘open’ communications networks); network standards/protocols, e.g. International Organisation for Standardisation (ISO), Institute of Electrical and Electronic Engineers (IEEE), Manufacturing Automation Protocol (MAP), Electronics Industry Association (EIA-485), Factory Instrumentation Protocol (FIP)
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
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<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
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</thead>
<tbody>
<tr>
<td><strong>P1</strong> describe the selection criteria and a practical application for a unitary, a modular and a rack-mounted programmable controller</td>
<td><strong>M1</strong> explain the benefits and limitations of a programmable controller for a specific application</td>
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</tr>
<tr>
<td><strong>P2</strong> explain the system hardware and software requirements for a programmable controller application</td>
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</tr>
<tr>
<td><strong>P3</strong> use a programming technique to produce, store and present a program that demonstrates the full range of instruction types</td>
<td><strong>M2</strong> explain the programming technique used and list the instruction types</td>
<td></td>
<td><strong>D1</strong> justify the choice of a specific programming technique and the methods used to produce, store and present the program</td>
</tr>
<tr>
<td><strong>P4</strong> explain the program documentation that has been used for a complex engineering application</td>
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</tr>
<tr>
<td><strong>P5</strong> describe the importance of health and safety when working with programmable controlled equipment</td>
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## Assessment and grading criteria

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<tbody>
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<td><strong>P6</strong> explain how one example of each of the three types of communication media would be selected for a specific programmable controller application.</td>
<td><strong>M3</strong> compare two different networks used for a modern programmable controller system.</td>
<td><strong>D2</strong> compare the current capabilities and limitations of a programmable controller and identify possible areas of future development.</td>
</tr>
<tr>
<td><strong>P7</strong> describe a network and relevant standards and protocols used for a modern programmable controller system.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

PLCs involve a complex mixture of computer technology, communication interfaces and software programming techniques.

The assessment strategy for this unit should consist of a mix of written technical reports and hands-on practical work. Annotated photographic evidence could also be a valuable tool to capture ‘on-site’ information and support learners’ written work.

Where the grading criteria refer to an ‘application’, this is intended to mean a real-world situation wherever possible. Although a different application could be used for different criteria, it would be reasonable to use the same or closely related applications throughout.

P1 and P2 are closely linked. P1 requires learners to describe the selection criteria and a practical application for a unitary, a modular and a rack-mounted programmable controller. In doing so, learners need to demonstrate their ability to recognise the different approaches to PLC operational activities. In describing the selection criteria learners should consider things such as cost, versatility and scanning time, together with relevant descriptions of the internal architecture (for example central processing unit (CPU), arithmetic and logic unit (ALU) etc.) and a practical application of each.

For P2, a comprehensive range of hardware and software requirements should be considered. For example, the power supply available may have quite different consequences for an application involving a field monitoring system as opposed to an installation in a factory. The amount of coverage of content for this criterion will be determined by the actual programmable controller application considered, but it is expected that learners should have at least four or five system hardware and software requirements indicated and explained.

P3 requires learners to use a programming method to produce, store and present a program that demonstrates the full range of instruction types. Learners are not expected to be fully competent programmers but their programs should be printed out, annotated where appropriate and stored.

The explanation required for P4 needs to cover all the related unit content, including hardware considerations, instruction types and documentation for testing. A ‘complex engineering application’ in this context is intended to mean some form of machine, a manufacturing process control operation or a conveyor system based on a real-life situation. Learners will need to provide some details of the complex application and go on to explain the documentation, for example the program instructions, testing documentation and forced facilities etc. associated with it. Ideally this would be a work-based application, although learners could be provided with a case study of a complex application.

P5 requires learners to describe the importance of health and safety when working with programmable controlled equipment. A range of ‘what if’ scenarios for various applications could be used to cover the full requirements of the unit content.

P6 requires learners to explain how one example of each of the three types of communication media (cable, connector, opto-isolator) would be selected for a specific programmable controller application. The key point here is for learners to recognise the media, understand how each one is selected, describe the main features and consider aspects such as frequency ranges and the technology to which they are being applied.
For P7, there is a possibility that the description of a network and relevant standards and protocols could become overly complex and involve a wide range of issues. Therefore, learners need to be restricted to describing just the general network architecture of perhaps an Ethernet, and provide details of the associated standards and what they generally imply.

M1 builds on the work carried out for pass criteria P1 and P2, as learners need to consider a specific application and apply their understanding of the selection criteria already used. The important point is that they can demonstrate ability in selecting an appropriate PLC type and have knowledge as to why it is an appropriate choice.

M2 can be clearly linked to pass criteria P3 and P4. To achieve M2, learners need to reflect on their choice of programming methods. In their justification (D1), learners should identify why one programming method has been chosen and make it clear why the others have been rejected.

M3 builds on the work undertaken to achieve P6 and P7. It requires learners to compare two different networks used for a modern programmable controller system. This should include details of the networks, standards and key differences. Learners need to demonstrate that they realise the important differences between networks and how they may influence the associated PLC systems.

Finally, D2 requires learners to reflect on the unit as a whole. The comparison could include aspects such as memory capacity, the types of PLC available, the growing development in networking technologies (for example wireless implications), the use of smart sensors and how this may impair the programme and feedback loops, how processor power may influence the programming method etc. Satisfactory achievement of this criterion will require learners to have considered the range of issues covered by the unit content and undertaken some independent research of trends and potential benefits.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<td>P1, P2, M1</td>
<td>Selection and Applications of PLCs</td>
<td>A written assignment requiring learners to demonstrate an understanding of PLC selection and application</td>
<td>A series of three written tasks. Learners provide a description of the selection and application of PLCs and explain hardware and software requirements. Learners are then given an application for which they choose a suitable PLC.</td>
</tr>
<tr>
<td>P3, M2, D1</td>
<td>Using Programming Techniques</td>
<td>Learners are required by their employer to produce a program for a specific programmable controller to meet a customer’s needs.</td>
<td>A practical programming task. Learners should produce a program, which should be printed out, annotated and stored.</td>
</tr>
<tr>
<td>P4, P5</td>
<td>Applications of Programmable Controllers</td>
<td>Learners investigate an industrial application of programmable controllers, and explain the documentation and health and safety considerations that relate to it.</td>
<td>A series of written descriptions/explanations.</td>
</tr>
<tr>
<td>P6, P7, M3, D2</td>
<td>Data Communications Media and Networks</td>
<td>Learners investigate the different forms of media, their selection criteria and their applications.</td>
<td>A series of written descriptions/explanations.</td>
</tr>
</tbody>
</table>
**Essential resources**

Centres will need access to a range of PLCs, communication media and interface devices. Software packages and tools should also be available to permit programming and implementation of device/applications for circuit performance and debugging. Learners will require access to a range of relevant manuals, reference data and manufacturers’ information.

**Indicative reading for learners**

**Textbooks**

ISBN 0750664320


Unit 29: Applications of Computer Numerical Control in Engineering

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

There are three basic principles to CNC machining. These are: positional control of the cutting tool relative to a workpiece using axes coordinates, the setting of cutting speeds and control of other functions such as the application of cutting fluid. To do this, machine tools need to be loaded with a series of instructions which is acted upon in sequence. These instructions are called program code and in this unit learners will be shown how to produce a working program using an industry-standard language.

The unit will consider two aspects of CNC machining. First, learners will investigate machine tools that have an in-built computer system. These are set up by a skilled operator who interprets data taken from an operational plan and converts this into program code.

Learners will then look at machine tools which are downloaded with code generated by a remote computer system running computer-aided design/manufacturing (CAD/CAM) software. The advantage that this type of system has over the stand-alone CNC machine is that a full three-dimensional (3D) simulation of the machining process can be carried out before any cutting of material takes place. This is an important aspect of economic manufacture because incorrect machining of a component will result in lost production and additional costs.

The unit has a high practical content and learners are expected to manufacture actual components. Learners will follow the various steps in the CNC process, starting with interpreting drawings and choosing a suitable machining process, correct cutting tools and work holding devices. They will then write and prove a part program, machine the product and carry out dimensional checking against specification.

The final part of the unit investigates the integration and use of CAD/CAM in the CNC machining process. Learners will be given a drawing file containing details of a component that they will then use to produce a 3D image of the component. Its functionality is confirmed before moving on to the simulation of the machining process using CAM software.

Once the machining operation has been proven and any problems corrected, the data needed to control the movements of cutting tools and other machine operations is downloaded from the computer into the machine’s control unit. Machining then takes place, with the program data saved for future use.
Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

**Learning outcomes**

**On completion of this unit a learner should:**

1. Understand the principles of computer numerical control (CNC) and machine structures
2. Be able to interpret a component specification and produce an operational plan for its manufacture
3. Be able to produce a part program and manufacture a component
4. Be able to use a computer aided design/computer aided manufacture (CAD/CAM) software package to generate a part program and manufacture a component.
Unit content

1 Understand the principles of computer numerical control (CNC) and machine structures

**CNC principles:** system, e.g. machine control unit, drive mechanisms, tool/workpiece interface, transducers, feedback, correction; datum points, e.g. machine, component; definition of parameters using numerical coding, e.g. position, movement, spindle speeds, cutting tools, clamping, application of coolant; CNC process, e.g. select machine, select tooling, identify machining sequence, calculate positional coordinates, calculate spindle speeds, programming, post-processing, setup sheet, verify and edit, store for future use

**Machine structures:** types, e.g. milling, drilling, turning centre, machining centre; designation of axes, e.g. 2 axis, 3 axis, x, y, z; motor and drive units, e.g. spindles, stepless drives, ball screw, stepper motors; transducers, e.g. positional, linear, rotary, analogue, digital, optical encoders, inductive, capacitive, magnetic; tooling e.g. modular, quick change, turret; tool transfer e.g. automatic, chain magazine, circular magazine; work holding, e.g. pallets, sub tables, rotary work changer, grid plate; swarf removal, e.g. chutes, chip controllers, conveyors; cooling, e.g. cutting fluid, cooling systems; computer hardware, e.g. keypad, display, Central Processing Unit (CPU), storage, cabling links, machine control unit (MCU); computer software, e.g. programming language, CAD/CAM DXF files; safety, e.g. overloading the cutting tool, guards, light barriers, interlocks, operator safety

2 Be able to interpret a component specification and produce an operational plan for its manufacture

**Component specification:** detailed drawing; material, e.g. steel, aluminium, polymer, other stable material; reference points, e.g. edge datum, centre line datum; dimensional, e.g. external, internal, centres distances, bore diameters, tolerances; surface finish, e.g. $R_a$, $R_z$ values

**Operational plan:** zero datums; work holding, e.g. clamps, fixtures, chucks, vices, setting points; changing components, e.g. pallets, sub tables, rotary work changer, grid plate; sequence of operations, e.g. loading, machining, roughing and finishing operations, measurement, unloading; calculations, e.g. cutter path coordinates for intersections, polar centres, arc centres, cutter compensation, cutting speeds, feed rates; use of trigonometric ratios, e.g. sine, cosine, tangent; cutter speed ($\frac{\text{surface speed}}{\pi} \times \text{cutter diameter}$); feed rate (feed per tooth $\times$ number of teeth $\times$ spindle speed); grouping of similar operations; canned cycles, e.g. irregular pockets, geometric, hole patterns; tooling, e.g. cutters, drills, reamers; other reference data, e.g. cutting fluids, special requirements relating to specific materials; inspection, e.g. first off proving against specification, on machine measurement; set up sheet and tool list
3 Be able to produce a part program and manufacture a component

*Part program*: user interface, e.g. menu bar, identification line, tool display window, system status; work/tool relationships, e.g. position, direction, amount of movement; rates of change, e.g. feed rates, spindle speeds; auxiliary functions, e.g. metric/imperial units, tool selection, cutting fluids, workpiece loading and holding, tool changing; CNC codes e.g. block number, preparatory functions (G codes); miscellaneous functions (M codes); other letter addresses (arc centres, spindle speed, feed rate); dimensional information, e.g. axis coordinates \((x, y, z)\), absolute, incremental; words, e.g. modal, non-modal; block format, e.g. block number, G code, coordinates; special function G codes, e.g. movement system, measuring system, tool compensation, canned cycles, subroutines; M codes, e.g. coolant, tool change, work holding, spindle speed, spindle direction

*Manufacture*: post-processing, e.g. transfer of files/data between systems, download program to machine tool; pre-manufacture, e.g. run through using graphics display on machine tool, prove program, dry run, load workpiece, stepping, adjust feed rates; run program, e.g. machine workpiece, first off inspect and check against specification, store verified program for future use, quality monitor; shutdown

4 Be able to use a CAD/CAM software package to generate a part program and manufacture a component

*CAD/CAM package*: hardware, e.g. CAD workstation, data storage, hard copy equipment, network system to download data to machine tools; software, e.g. Autodesk Inventor, Esprit, Solid Works, Edge CAM, Denford VR milling/turning; universal formats, e.g. extensions (such as DXF, IGS, AI, EPS, PLT, NC), proprietary formats (such as DWG, CDR, CDL, GE3, NC1, BMP, MSP, PCX, TIF)

*Part program*: e.g. 3D geometric model using CAD software, select machining operations, select tooling, generate CNC program using CAM software, simulation of tool changing and tool paths in the machining process, correction and editing

*Manufacture*: post-processing, e.g. transfer of files/data between systems, download program to machine tool; manufacturing, e.g. load and clamp workpiece, set tooling, initiate program cycle, machine workpiece, first off inspect and check against specification, store verified program for future use, quality monitor; shutdown
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<thead>
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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
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<tbody>
<tr>
<td><strong>P1</strong> describe the principles on which a machine tool operates when controlled by a CNC system</td>
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<tr>
<td><strong>P2</strong> describe, with the aid of suitable diagrams, the structure of a given CNC machine type</td>
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</tr>
<tr>
<td><strong>P3</strong> interpret the specification for a given component and produce an operational plan for its manufacture</td>
<td><strong>M1</strong> explain the importance of producing an accurate and detailed operational plan for a component that is to be manufactured using a CNC machine tool</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> produce a part program for a given component</td>
<td><strong>M2</strong> explain the importance of correct programming and setting up in order to produce a component to a required specification.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong> manufacture a component using a two- or three-axis CNC machine</td>
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</tr>
<tr>
<td><strong>P6</strong> use a CAD/CAM package to produce a part program from a given component detail drawing</td>
<td><strong>M3</strong> test the program explaining how it meets the requirements of the drawing</td>
<td><strong>D1</strong> compare and contrast the effectiveness of a CAD/CAM method of manufacturing a component to that of using CNC part programming</td>
<td></td>
</tr>
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</table>
### Assessment and grading criteria

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<tr>
<td><strong>P7</strong> manufacture a component on a CNC machine using a post-processed program generated using CAM software.</td>
<td><strong>M4</strong> explain how the manufactured component meets the requirements of the program.</td>
<td><strong>D2</strong> evaluate the cost benefits of using CAD/CAM software when programming CNC machines.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

This unit could be assessed through the use of five assignments. To achieve a pass grade, learners need to have an understanding of the principles of CNC and be able to manufacture a component. It is not expected that they should be able to program and set up CNC machines at an expert level, and this should be taken into account when designing assignments.

It is suggested that the first assignment covers grading criteria P1 and P2, with learners being asked to produce a written report. Evidence for P1 should be generic and not specific to a particular type of machine. There is a lot of material that learners will have access to and care should be taken to ensure the validity of the evidence they provide.

P2 relates to a given type of machine, details of which should be specified in the assignment brief. Some learners may be working in a CNC environment and if they have specialised knowledge about a particular machine tool they could use this towards their evidence for P2.

Grading criteria P3 and M1 complement each other and can be assessed through a second assignment. The assignment brief covering P3 should provide learners with hard copy information about the component and a detailed drawing presented in printed form to an acceptable industry standard. The brief could also include a pro forma for setting out the operational plan, although learners working in a CNC environment may wish to use their own style of layout. Care should, however, be taken to ensure there are sufficient aspects of an operational plan covered by the content section for learning outcome 2. It must be remembered that a plan for CNC machining is different from one for traditional machining.

Further evidence in the form of annotated drawings and specification sheets, calculations to support machining decisions such as speeds and feeds and trigonometric ratios to calculate coordinates and intersections will also be needed to support P3. Evidence presented for M1 should make reference to the operational plan produced for P3 but additional evidence drawn from wider sources should be included.

The third assignment could be designed around P4, P5 and M2. It will add realism if the same component is used for both pass criteria. Learners should be given a pre-produced operational plan to work from, although if they wish they could use the one produced for P3, providing it is fit for purpose. The only requirement is that the part program and manufacturing relate to a single component which is significantly more complex that the one looked at in Unit 31: Computer-aided Manufacturing. Three-axis machining would be the preferred option, using something like a vertical milling machine. As the assignment involves a lot of practical work, evidence presented for assessment should include screenshots, witness statements, observation records and annotated digital images.

The fourth assignment could cover P6, P7, M3, M4, D1 and D2. Learners who wish to gather evidence for D1 will probably want to use the component specification provided in the third assignment so that they can contrast the effectiveness of the two methods of programming. The starting point for P6 is a detailed drawing and this should be given to learners as a file which can be opened using CAD/CAM software. With the agreement of the tutor, some learners who are taking the CAD unit may wish to use a component that they have previously drawn, but it needs to be in a form that can be easily processed.
Evidence presented for assessment should include screenshots showing tool path simulation, witness statements, observation records and annotated digital images. A written task will need to be given asking learners to compare and contrast the effectiveness of a CAD/CAM method of manufacturing a component to that of using CNC part programming (D2). They will obviously need to identify benefits and limitations of each approach and draw valid supported conclusions. The focus of D1 is very specific and some of the evidence presented could relate to the tasks undertaken to achieve P4, P5, P6 and P7. M3 and M4 are logical extensions of P6 and P7 respectively requiring explanations of how the entities produced meet the original requirements.

When writing about their experiences, learners should include an evaluation of their own effectiveness in using the two systems of manufacture. Factors to be considered might include something on how easy it was to learn the software packages, ease of program editing and the lead times needed to produce the components. Discussions with a manufacturing engineer who works for a company using both systems or which has moved from CNC part programming to an integrated CAD/CAM setup could be used as further evidence.

A further task can be included to cover D2, in the form of evaluative writing supported by evidence gathered from published case studies. Learners should consider the effectiveness of CAD/CAM programming in the wider context and not just concentrate on the components that they have manufactured.

Some of the evidence for D2 could be come from work produced for Unit 31: Computer-aided Manufacturing and it may be possible to integrate assignments across units. Because there are well documented examples of the cost benefits achieved by companies who use CAD/CAM software to program CNC machines, care must be taken to ensure that what the learner presents as evidence is authentic. Use could be made of experience from Unit 44: Setting and Proving Secondary Processing Machines, particularly about work holding and machining parameters. Where appropriate, employed learners should be given the option of using examples taken from their own company.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2</td>
<td>CNC Principles and Machines</td>
<td>An assignment requiring learners to demonstrate their knowledge of the underlying principles of CNC machines and CNC machine structures.</td>
<td>Two written tasks for which learners need to produce an explanation of the principles on which machine tools operate and a written description of CNC machine structure.</td>
</tr>
<tr>
<td>P3, M1</td>
<td>Component Specifications and Operational Plans for Manufacture</td>
<td>A practical assignment requiring learners to interpret a component specification and produce a plan for its manufacture.</td>
<td>A practical task for which learners are provided with a detailed drawing and information about a component that they need to interpret. Learners produce an operational plan to manufacture the product on a CNC machine. A further written task gives learners an opportunity to explain the importance of an accurate and detailed plan.</td>
</tr>
<tr>
<td>Criteria covered</td>
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</tr>
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</tr>
<tr>
<td>P4, P5, M2</td>
<td>Part Programs for Manufacturing Components</td>
<td>A practical assignment requiring learners to produce a part program and use it to manufacture a component.</td>
<td>Practical tasks in which learners are given a pre-produced operational plan for which they produce a part program and manufacture a component using three-axis machining.</td>
</tr>
<tr>
<td>P6, P7, M3, M4, D1, D2</td>
<td>Using CAD/CAM to Manufacture Components</td>
<td>A practical assignment supported by written tasks requiring learners to demonstrate their ability to use CAD/CAM to manufacture a component.</td>
<td>Practical and written tasks. Learners are given a detailed drawing for which they write a part program. Learners then need to use their post-processed program to manufacture the component. Written tasks will ask learners to compare CAD/CAM to CNC part-programming and evaluate the cost benefits of CAD/CAM.</td>
</tr>
</tbody>
</table>
Essential resources

In order to deliver this unit, centres will need to have 2D/3D commercial CAD software and CAM software that integrates with the CAD package used for designing. They will also need to have access to a two- or three-axis CNC machine tool and a two- or three-axis machine tool which can be downloaded with data from a computer system.

Indicative reading for learners

Textbooks


Unit introduction

The industrial processes used to produce welded joints rely on the application of heat to melt and fuse the materials together. The amount of heat used varies according to the process, but one common factor is that the metallurgical structure of the metal will be changed to some extent by the welding operation.

This unit gives learners an understanding of the effect that the heat input has on a welded component. The unit is suited to welders and those responsible for the specification of the welding process and any post-weld heat treatments. The unit will develop learners’ knowledge of the structure of pure metals and the effects of adding alloying elements. Learners will develop an understanding of the effect that heat has on metals and their alloys once they have been welded, and how this influences the performance of a welded component. Learners will also gain knowledge of the post weld heat treatment processes that are available to improve the performance of the structure and relieve stress. The testing of welds is also covered in the unit so that learners appreciate the need for a component to meet a quality standard.

Learners will perform a range of practical and investigative tasks to develop their understanding of different welding processes and the suitability of their application. Learners will prepare materials for welding and the post-welding treatments of welded materials. Identification of defects is vital in ensuring the quality of the finished product and learners will demonstrate their knowledge of the techniques employed in defect detection and the quality standards used in industry.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Know the physical features of welding processes
2. Know the effects of welding and select post-weld heat treatments
3. Understand the weldability of metals
4. Be able to use and interpret quality standards and weld testing techniques.
Unit content

1 Know the physical features of welding processes

Welding processes: main processes, e.g. manual metal arc (MMA), metal-arc gas shielded (MAGS), tungsten arc gas-shielded (TAPS), oxy-acetylene;
additional processes, e.g. resistance (such as spot, seam), friction, flash butt, laser, electron beam, explosive, exothermic (thermit), capacitor discharge stud welding, friction stir welding; choice of processes; working environment, e.g. workshop, site work, suitability of machinery and plant

Electric arc: alternating current (AC); direct current (DC); heat distribution at the anode and cathode; effect of magnetic fields; applications of AC and DC; consumable and non-consumable electrodes; metal transfer and deposition; plasma-arc

Shielding gases: functions, e.g. atmospheric protection, arc initiation; shielding gases, e.g. inert gases, argon, helium; active gases used in mixtures, e.g. carbon dioxide (CO2), nitrogen, oxygen; applications, e.g. MAGS, TAPS, plasma-arc

Electrode coverings and fluxes: functions of coverings and fluxes, e.g. atmospheric protection, slag, removal of impurities, alloying, arc initiation; composition, e.g. basic, rutile, cellulosic, iron powder; fluxes, e.g. fused, agglomerated; applications of coverings and fluxes, e.g. MMA welding, submerged arc welding, braze welding

Oxy-acetylene combustion: chemical composition of the inner and outer envelope; heat distribution; applications of flame types, e.g. neutral, oxidising, carburising

2 Know the effects of welding and select post-weld heat treatments

Effects of welding heat input: distortion control, e.g. pre-setting, pre- and post-heating, total heat input, weld deposition (skip and back step) techniques; effects, e.g. distortion (expansion and contraction), expansivity, residual stress; effects of cooling rate, e.g. hardening, grain growth, cracking; structure of the welded joint e.g. heat-affected zone (HAZ), crystal structure (such as equi-axed, columnar), grain growth; heat distribution during welding, e.g. thermal gradients, heat flow, joint configuration (butt, tee, cruciform); use of chills; comparison of processes

Post-weld heat treatments: for ferrous metals, e.g. annealing (full, process), normalising; for heat treatable aluminium alloys, e.g. solution treatment, precipitation hardening

3 Understand the weldability of metals

Weldability: factors, e.g. melting temperature, carbon equivalent, rate of heating and cooling (thermal shock), thermal conductivity, residual stress, degree of restraint (the rigidity of the construction), similar and dissimilar metals; dilution, hardenability, dissolved hydrogen, pre- and post-heat temperature; impurities, e.g. phosphorous (cold shortness), sulphur (hot shortness); mechanical properties, e.g. tensile strength, impact strength
4 Be able to use and interpret quality standards and weld testing techniques

*Weld test techniques*: non-destructive, e.g. visual (weld gauges, dimensional), radiographic (such as x-ray, gamma ray), ultrasonic, dye penetrant, magnetic particle; destructive, e.g. fracture, bend test, macro and microscopic examination, tensile, fatigue, hardness

*Weld defects*: visual (surface defects), e.g. undercut, overlap, excess weld metal, leg length of fillets, concavity, cracking (such as cold cracking, hot cracking, crater, transverse, longitudinal, centre-line, HAZ), blowholes, oxidation, restarts; internal, e.g. porosity, inclusions (such as slag, metallic, gaseous), lack of inter-run fusion, cavities

*Quality standards*: in relation to relevant standards, e.g. British Standard/European Standard BS EN 970, BS EN 1011, BS EN ISO 10042, BS EN ISO 15607, BS EN ISO 15609, BS EN ISO 15614, American Society of Mechanical Engineers (ASME) IX
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
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<td>To achieve a pass grade the evidence must show that the learner is able to:</td>
</tr>
<tr>
<td><strong>P1</strong> select suitable welding processes for four given applications</td>
</tr>
<tr>
<td><strong>P2</strong> describe the physical features of an electric arc used in a welding process</td>
</tr>
<tr>
<td><strong>P3</strong> describe the function of two given shielding gases and two electrode coverings/fluxes used in welding processes</td>
</tr>
<tr>
<td><strong>P4</strong> describe oxy-acetylene combustion and its application when using gas welding equipment</td>
</tr>
<tr>
<td><strong>P5</strong> describe three methods of controlling the effects of heat input when using welding processes</td>
</tr>
<tr>
<td><strong>P6</strong> describe the effect of heat input, heat distribution and cooling rate on the grain structures of two welded joints</td>
</tr>
<tr>
<td><strong>P7</strong> identify suitable post-weld heat treatment processes for joints in steel and aluminium alloys that have been welded</td>
</tr>
</tbody>
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## Assessment and grading criteria

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<td><strong>P8</strong> describe the factors that will affect a given metal’s weldability</td>
<td><strong>M3</strong> explain how impurities affect quality in terms of the weldability and material properties of a welded joint.</td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> use two weld testing techniques to detect surface defects and internal weld defects in accordance with quality standards</td>
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<td></td>
</tr>
<tr>
<td><strong>P10</strong> produce a test procedure for a destructive or non-destructive weld test to detect weld defects in welded components.</td>
<td></td>
<td><strong>D2</strong> analyse the defects found in a component that has been weld tested and identify possible causes in relation to the heat input.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

The learning outcomes of this unit may be linked with those of other units, in particular Unit 27: Welding Technology. Written assignments should be supported with appropriate photographs and diagrams.

Pass criteria P1, P2, P3 and P4 could be achieved by learners selecting and describing the functions and features of welding processes and their application in industry. Learners’ responses could include both written and oral questioning. The four given applications should include processes across the range of those outlined in the unit content. A further written task to cover M1 should ensure that learners cover the range of processes and physical features identified in the unit content.

Achievement of P5 could be achieved by means of a written task. To enable learners to understand the effects of distortion, it may be appropriate for them to participate in an associated practical task. This could, for example involve measuring the angle between two plates before and after the welding of a tee fillet joint. Evidence for P6 is also likely to come from a written task in which learners are asked to consider two joints that are subjected to extremes of heat input due to the process parameters. One joint could be in thin metal, welded by a process with a high deposition rate (for example MAGS or laser), compared with a thicker metal welded using a slower deposition process (for example MMA or oxy-acetylene welding). A further task covering P7 could require learners to investigate and recommend post-weld heat treatment processes appropriate to welded joints in steel and aluminium alloys. Another written task can then build on this to cover M2.

For P8, a written task could be used based on a range of factors and impurities known to affect the weldability and properties of metals. This could be extended to also cover M3, with learners providing an explanation of how impurities can affect welded joints.

A written task covering P9 should ask learners to produce a procedure for carrying out non-destructive and destructive tests, as identified in the unit content. There is an opportunity to set different procedures for the range of learners or to concentrate on testing techniques that may be found in the learners’ workplace, where applicable. P10 could be achieved using a combination of practical assessments and research. Learners could either use welds produced in the welding workshop or commercially produced weld specimens with known defects, to correctly detect surface and internal defects in welds relevant to a given quality standard. Learners should perform this on a range of materials, ferrous and non-ferrous. While this criteria is suitable for assessing by a written report, the assignment may be assessed using an oral presentation where photographs, diagrams and samples should be used.

To achieve distinction criterion D1 learners need to explain post-weld heat treatment processes and discuss the advantages and disadvantages. This will combine the knowledge gained in P1 to P7 as this will depend upon the materials, welding process and the heat input.

Assessment of D2 could be in the form of a written task though this may be better assessed as part of the oral presentation suggested for the assessment of P10. Learners would be expected to demonstrate their knowledge of not only the applications and operation of the weld testing technique, but also that of the quality standards and welding process used.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, P4, M1</td>
<td>Welding Processes</td>
<td>An assessment based on learners’ knowledge and investigations into the physical features of welding processes.</td>
<td>This assessment will use a written report and oral questions to assess learners’ knowledge across a range of welding processes. Learners will need sufficient knowledge to select appropriate processes for given applications. They will also need to know the physical features of those processes. Learners will need to explain welding processes in terms of how the heat is input, and how the fusion of the material takes place to produce the weld.</td>
</tr>
<tr>
<td>P5, P6, P7, M2, D1</td>
<td>The Effects of Welding</td>
<td>This assessment requires learners to investigate and report on the effects of welding in terms of controlling distortion, the grain structure and the heat treatment of materials.</td>
<td>A written assessment based on joints or components that learners have investigated in the workshop, these may have been produced by learners, or commercially produced. Those learners who are employed may benefit from applying procedures used in the workplace. The effects of welding should be considered in context with the welding process used. Learners may also explain the effects of welding and analyse these effects further.</td>
</tr>
</tbody>
</table>
### Criteria covered

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>P8, M3</td>
<td>Weldability of Metals</td>
<td>An assessment that focuses on the weldability of materials. Learners will report on their research and tutor-led activities.</td>
<td>This written assessment considers the factors that affect the weldability of a material and the effect of impurities on the welded material. An opportunity is given to explain the effect of impurities on a welded joint.</td>
</tr>
<tr>
<td>P9, P10, D2</td>
<td>Weld Testing and Quality Standards</td>
<td>This assessment reports on the findings of practical investigations when working to quality standards applicable to weld testing.</td>
<td>This may be assessed in the form of a written report, but would be better assessed by oral presentation (which may utilise ICT to produce a visual presentation). Learners should present a test procedure that has been produced to identify weld defects. Learners should also present information on their use of weld testing techniques and the defects found, comparing them to relevant quality standards.</td>
</tr>
</tbody>
</table>

### Essential resources

Centres will require access to welding equipment to allow learners to observe at least one welding process. Weld testing facilities will be required for visual examination and at least one destructive and one non-destructive test. Centres will need samples which are commercially produced which use a range of welding processes.

### Indicative reading for learners

**Textbooks**


Unit introduction

An understanding of how computer-aided manufacturing (CAM) systems operate in an engineering business is important for anyone thinking of a career in the design and manufacture of products.

This unit aims to develop an appreciation of the use of computer systems in a world-class manufacturing environment and how they are applied to product design and manufacture. Emphasis is placed on the need for a total approach to product development, in particular the interface between the various functions of the design and make process and the use of simultaneous engineering.

Learners will start by investigating how CAM systems are used to increase the profitability of a business by reducing manufacturing costs, improving quality and being more responsive to customer needs. This is followed by a look at how simultaneous engineering is used to bring together the many functions of a manufacturing business so that there is a team-based, multi-disciplinary approach to problem solving. Learners then investigate how simultaneous engineering can be used to meet the demands of a customer-driven economy where people expect an off-the-shelf service for customised products.

The unit covers how newly designed components are modelled using three-dimensional (3D) CAD software so that their functionality can be assessed and any errors corrected before the machining process is simulated using CAM software. Raw materials and the cutting of metal are expensive and getting it right first time is a crucial aspect of economic manufacture.

Learners will investigate how manufacturing processes can be automated by using industrial robots to move materials and components between the machine tools and the workstations that make up a flexible manufacturing system (FMS). Finally, learners will be given the specification for a component, use CAD software to design it and use CAM software to produce a set of instructions for downloading to a machine tool which could be used to make it.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand the benefits of CAM and the significance of simultaneous engineering
2. Understand how the CAD/CAM interface operates and modelling is used to simulate the manufacturing process
3. Understand the use of industrial robots and flexible manufacturing systems in engineering
4. Be able to design a simple component and generate a programme for a CNC machine using a CAD/ CAM software package.
Unit content

1 Understand the benefits of CAM and the significance of simultaneous engineering

Benefits of CAM: increased profitability, e.g. reduced machine set-up times, greater flexibility in terms of batch sizes, reduction in lead times, reduction of labour costs, lower unit costs, optimised use of cutting tools, production of complex shapes; improvements in quality, e.g. elimination of human error, consistent accuracy; greater responsiveness to the requirements of the customer; competing in the world market place

Simultaneous engineering: parallel operation of tasks; multi-discipline team-based working, e.g. marketing, design, modelling, rapid prototyping, manufacturing, development; time-based management, e.g. integration of activities, lean manufacturing, total quality management (TQM), shorter development times, faster time to market, right first time, improved communication

2 Understand how the CAD/CAM interface operates and modelling is used to simulate the manufacturing process

CAD/CAM interface: CAD, e.g. product design using industry-standard CAD software, modification of design ideas, production of working drawings; CAM, e.g. generation of part programmes, scheduling of raw materials; specialised linking software, e.g. edgeCAM, Autodesk Inventor/Esprit, SolidWorks; universal formats, e.g. extensions (such as DXF, IGS, AI, EPS, PLT, NC), propriety formats (such as DWG, CDR, CDL, GE3, NC1, BMP, MSP, PCX, TIF)

Modelling and simulation: use of CAD/CAM software, e.g. 3D modelling of the product, simulation of tool changing and toolpaths in the machining process, simulation of sequential manufacturing processes, rapid prototyping; benefits, e.g. elimination of machining errors, reduction in scrap rates

3 Understand the use of industrial robots and flexible manufacturing systems in engineering

Robots: applications, e.g. pick and place systems, product handling, product assembly, machine loading, safe operation, codes of practice (Health and Safety Executive (HSE) HSG43, Reducing error and influencing behavior HSG 48, Provision and Use of Work Equipment Regulations (PUWER) 1998); advantages, e.g. consistency of performance, 24/7 continuous working, reduced cycle times; limitations, e.g. high standard of maintenance required, precise programming needed, computer systems failure will cause breakdown, new products require complete reprogramming, certain processes still need a skilled operator, complex and expensive equipment

Flexible manufacturing systems: benefits, e.g. production of different parts without major re-tooling, efficient production of customised products, ease of responding to changes in product mix and production schedules, lean manufacture; processing machines, e.g. CNC machine tool, machining centre, flexible cell, welding station, assembly; loading and unloading systems, e.g. material handling, pick and place, fixed position robot, conveyors; coordination of the working schedule, e.g. process monitoring by computer, optical recognition, inspection, TQM
4 Be able to design a simple component and generate a programme for a CNC machine using a CAD/CAM software package

Using CAD/CAM software: hardware, e.g. CAD workstation, data storage, hard-copy equipment, network system to download data to machine tools; software, e.g. 2D/3D CAD, databases, single-component CAD files, part programming, macros, cutter path simulation; post-processing, e.g. transfer of post-processed files/data between systems, download to machine tools, inspection and quality management
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td>P1</td>
<td>explain how the use of a CAM system can benefit the operation of a manufacturing business</td>
<td>M1 describe the criteria used to assess the viability of introducing CAM and simultaneous engineering systems into a business</td>
<td>D1 analyse a current low-technology manual manufacturing system for suitability to move to a CAM environment</td>
</tr>
<tr>
<td>P2</td>
<td>describe the strategies used in simultaneous engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>explain how the interface between design and manufacture can be integrated using suitable CAD/CAM software</td>
<td>M2 explain the cost benefits of moving from low-technology manual manufacturing to high-technology automated manufacturing</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>explain the reasons for carrying out modelling of a component and simulation before actually cutting metal</td>
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<td><strong>P5</strong> describe the applications, advantages and limitations of industrial robots</td>
<td><strong>M3</strong> explain the use and operation of robots to move parts between workstations in a flexible machining system</td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> explain why a flexible manufacturing system will produce productivity gains for a business deploying a range of processing machines, loading and unloading systems and coordinated work schedules</td>
<td><strong>M4</strong> explain the hardware and software used for this process.</td>
<td><strong>D2</strong> discuss post-processing procedures used.</td>
</tr>
<tr>
<td><strong>P7</strong> use appropriate software to design a simple component and produce a part program which could be post-processed and used to manufacture it on a CNC machine.</td>
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</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment of this unit could be through five assignments.

It is suggested that the first assignment covers P1 and P2, with learners being asked to support their thoughts with evidence taken from published case studies relating to well-known companies (for example Toyota and Airbus Industries). It is important that learners demonstrate a good understanding of the reasons why, in a customer-driven, global market environment, a manufacturing company can survive only if it uses smart systems in the operation of its business. There is scope to expand this first assignment to include M1. A visit to an engineering company which has moved to using world class manufacturing systems would be a good way of gathering research information.

Grading criteria P3 and P4 complement each other and can be assessed through a second assignment. Learners should not be expected to demonstrate proficiency in the use of CAD/CAM software. A visit to a company to look in detail at the way a component is designed and manufactured would be a useful way to gather evidence. This could involve talking to a CAD designer and being shown the processes of design, modelling and manufacturing. There is scope to include M2 in this assignment.

A third assignment could cover grading criteria P5 and P6. Thought needs to be given to structuring the tasks so that learners restrict themselves to just the applications of robots and do not get sidetracked into explaining in great detail their operating principles. As recommended earlier, restricting learners to three applications will be enough to produce valid evidence to meet P5. As criterion M3 builds on P5 and P6 it can be a part of the third assignment.

The fourth assignment could be a practical activity covering P7. The component to be designed should be kept very simple as learners are not required to prove competence in using high-level design skills. As suggested earlier, a simple embossed key fob design which uses the line, arc, diameter and text commands in its design will produce a profile sufficiently complex for a part program and its post-processing. Screen prints could be used as evidence of tool path simulation, supported by witness statement or observation records of learner performance.

M1 builds on P1 and P2. To achieve it there should be evidence of thought having been given to the pressure on design and manufacturing engineers to optimise resources and use business improvement techniques.

M2 links into P3 and P4 but also draws on knowledge from P1 and P2. Explanations should be supported by examples taken from real companies which have successfully moved from low-technology to high-technology manufacturing systems and might include figures for the amounts of cost savings achieved.

M3 requires a greater understanding of how a robot operates and will build on knowledge gained when achieving P5 and P6. Evidence presented should be at a systems (black box) level and the assignment tasks should not be asking for detailed knowledge about, for example, the internal workings of a specific drive or sensor unit within the robot. Tasks based on a scenario which relates to a specific machining system could be used to generate evidence. Learners are not expected to explain how the actual machining functions operate because the criterion relates only to the handling and moving of parts. M4 requires an explanation of the hardware and software used for component design.
Grading criterion D1 builds on content covered in learning outcomes 1, 2 and 3 and could be a very detailed piece of writing based around a scenario. For this reason it might be best covered by a fifth assignment. Learners could assume the role of a manufacturing engineer who has been tasked with presenting proposals to senior management on the implications and suitability of moving from low-technology manufacturing to a CAM environment. There are a lot of well documented examples of how this has been achieved successfully by well-known companies and care must be taken to ensure that what learners present as evidence is authentic. Where appropriate, employed learners should be given the option of analysing their own company. D2 requires a discussion of the post-processing utilised in the component designed in P7.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, P2, M1</td>
<td>Using CAM and Smart Systems in an Engineering Business</td>
<td>Learners have been asked by their employer to produce a report on the benefits of using CAM and the strategies used in simultaneous engineering.</td>
<td>A written assignment for which learners produce a report detailing the benefits of CAM to a modern manufacturing business and the use of simultaneous engineering.</td>
</tr>
<tr>
<td>P3, P4, M2</td>
<td>CAD/CAM Interfacing</td>
<td>Learners need to provide an explanation of how CAD/CAM software is integrated and the reasons for simulation for a local manufacturer considering moving over to CAM systems.</td>
<td>A written assignment for which learners produce a report into the interface between design and manufacture and the purpose of simulation. A further task would require learners to explain the cost benefits of modern manufacturing systems.</td>
</tr>
<tr>
<td>P5, P6, M3</td>
<td>Industrial Robots and Flexible Manufacturing Systems</td>
<td>Learners have been asked by their employer to produce a report on the benefits and limitations of using industrial robots and the use of flexible manufacturing systems.</td>
<td>A written assignment consisting of tasks requiring learners to discuss the applications of industrial robots and explain why a flexible manufacturing system can produce gains for a business.</td>
</tr>
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<tr>
<td>P7, M4, D2</td>
<td>Using CAD/CAM Software</td>
<td>Learners need to design a component for a client and produce a part program for its manufacture.</td>
<td>A practical assignment for which learners will need to design a component and produce the part program necessary for its manufacture. Evidence is likely to be supported by screen prints and tutor observation records.</td>
</tr>
<tr>
<td>D1</td>
<td>Evaluating the suitability of a CAM Environment</td>
<td>Learners have been asked by senior management to investigate the implications and suitability of moving from low-technology manufacturing to a CAM environment.</td>
<td>A written assignment for which learners produce a report detailing the suitability of moving to a CAM system for a low-technology manual system.</td>
</tr>
</tbody>
</table>

**Essential resources**

Centres will need to give learners access to 2D/3D commercial CAD software and CAM software which integrates with the CAD package used for designing.

Extracts from appropriate standards and legislation and access to industry-standard CNC machining centres and flexible manufacturing systems are also needed.

**Indicative reading for learners**

**Textbooks**


Unit 32: Electronic Circuit Design and Manufacture

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

A diverse range of techniques is used in the manufacture of electronic circuits. The techniques used for manufacturing prototype electronic circuits are often significantly different from those used in high volume production. This unit provides an introduction to prototype manufacture, as well as the techniques used for the mass production of electronic circuits.

Large-scale electronic manufacture generally involves fully automated assembly techniques using equipment that can produce complex circuits quickly, accurately, at low cost and with minimal human intervention. Alternatively, if only one circuit is to be built (perhaps for evaluation or testing purposes), then a hand-built prototype is much more appropriate.

Computer-aided design (CAD) and computer-aided manufacture (CAM) are widely used in the production of electronic circuits. This unit will introduce learners to the use of modern production methods, including printed circuit board (PCB) layout and computer numerical control (CNC) drilling and mask production.

When an electronic circuit is developed for a commercial application it is usually tested and proved using computer simulation prior to manufacture. This unit will give learners an opportunity to develop and test circuits using SPICE (simulation program with integrated circuit emphasis) software. The unit also gives learners an understanding of the use and application of surface mount technology (SMT) in the manufacture of electronic circuits.

The unit will also enable learners to experience and gain skills in the full cycle of design, manufacture and testing of an electronic circuit assembled on a simple single-layer printed circuit board.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit an learner should:

1. Know the design processes and production methods used in the manufacture of a printed circuit board
2. Understand the use of software techniques and thermal analysis techniques in the design, simulation and manufacture of an electronic circuit
3. Understand the use and application of surface mount technology in the manufacture of an electronic circuit
4. Be able to design, manufacture, assemble and test a prototype printed circuit board for a given electronic circuit.
Unit content

1 Know the design processes and production methods used in the manufacture of a printed circuit board

*Design processes:* design strategy, e.g. methodology and techniques used in its realisation (build type, number of layers, net rules, track and gap, via size); design tools e.g. PCB design software, schematic design and capture, creating and modifying component geometries; creating and modifying schematic diagrams; design verification and design rule checking for both tracking and component layout; auto-routing tools; related documents, e.g. parts lists, bills of materials, machine files, component geometries

*Production methods:* artwork generation; board production, e.g. etching, masking, drilling, silk screening, cutting; automated production techniques, e.g. robotics and automated assembly, CNC drilling and mask production; soldering methods, e.g. wave soldering, automated wave soldering; fabrication and assembly requirements, e.g. placement on one side, placement on both sides, combination of surface mount technology (SMT) and through-hole technology (THC); test strategy, e.g. electromagnetic compatibility (EMC), signal integrity, high frequency requirements; manufacturability analysis

*Types of PCB:* laminates, e.g. single and double sided, plated through-hole, fibreglass-resin laminate; solder mask over bare copper (SMOBC); tinned; conventional component and surface mount; single, double and multi-layer boards; gold plated contacts, flexible and membrane PCB, chip-on-board (COB)

2 Understand the use of software techniques and thermal analysis techniques in the design, simulation and manufacture of an electronic circuit

*Computer-aided design (CAD) software:* simulation program with integrated circuit emphasis (SPICE) software; direct current (DC) analysis, alternating current (AC) small-signal analysis; more complex analysis methods, e.g. mixed-mode analysis, transient analysis, pole-zero analysis, distortion analysis, sensitivity analysis, noise analysis, thermal analysis; software integration methods e.g. export and import data, links with companion software for circuit layout and PCB manufacture

*Thermal analysis:* heat dissipation methods; thermal ratings of semiconductor devices; thermal calculations, e.g. total power dissipation, thermal resistance, \( \theta_T = \theta_{JC} + \theta_{CS} + \theta_{ST} \), junction temperature, \( T_J = (P_I \times \theta_T) + T_A \), temperature rise above ambient, \( \Delta_T = P_I \times \theta_T = T_J - T_A \), de-rating, correct rating for thermal dissipator/heatsink
3 Understand the use and application of surface mount technology in the manufacture of an electronic circuit

*Surface mount technology (SMT):* types of SMT device, e.g. passive components (resistors, capacitors, inductors and transformers), active components (transistors, diodes and integrated circuits), connectors and sockets; surface mount device (SMD) outlines, packaging and storage; manufacturers’ markings and supporting data; hybrid circuits and multi-chip modules (MCM)

*SMT circuit manufacturing:* manufacturing methods, e.g. use of solder pastes, flow and wave soldering equipment; SMT quality assurance methods, e.g. batch testing, statistical methods; SMT component reliability and testing of finished SMT assemblies; assembly-level packaging and interconnection

4 Be able to design, manufacture, assemble and test a prototype printed circuit board for a given electronic circuit

*PCB design:* single-sided printed circuit board for a given electronic circuit design that includes no more than four active devices, e.g. transistors, diodes and conventional dual in-line (DIL) packaged integrated circuits; associated passive components, e.g. PCB mounted resistors, capacitors, inductors, transformers; means of connection, e.g. external controls, connectors, power sources; layout techniques based on the use of electronic CAD to generate PCB master artwork

*PCB manufacture:* developing, etching, drilling

*Electronic circuit assembly:* component mounting, soldering

*PCB and circuit testing:* functional testing using a supplied test specification to determine circuit design inputs and outputs, e.g. test-point voltages, output signals
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
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<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td><strong>P1</strong> describe the processes used in the design of both a single and multi-layer PCB for electronic circuits of different complexity</td>
</tr>
<tr>
<td><strong>P2</strong> describe typical production methods used in the manufacture of both a single and a multi-layer PCB for electronic circuits of different complexity</td>
</tr>
<tr>
<td><strong>P3</strong> explain how computer aided design software is used to analyse an electronic circuit prior to manufacture</td>
</tr>
<tr>
<td><strong>P4</strong> explain the need for thermal analysis and effective heat dissipation for an electronic circuit</td>
</tr>
</tbody>
</table>
## Assessment and grading criteria

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</tr>
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<tbody>
<tr>
<td><strong>P5</strong> explain the use of SMT in the manufacture of an electronic circuit and give two examples of the outlines and packages used for surface mounted devices</td>
<td><strong>M4</strong> evaluate the use of typical quality assurance methods in the manufacture of electronic circuits using SMT</td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> explain methods used for the manufacture of an electronic circuit using SMT</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> design, manufacture and test a prototype printed circuit board for a given electronic circuit to a valid standard.</td>
<td><strong>M5</strong> justify the design of the printed circuit board with regards to function and suitability for use.</td>
<td><strong>D2</strong> evaluate the design and manufacture of the prototype PCB and circuit and make appropriate recommendations for mass production.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

P1 and P2 are closely related and evidence could be gathered from either an extended case study or from research and investigation. Case studies and investigations should ideally be based on production techniques and manufacturing processes that are used locally. Learners would benefit from visits to local industry to view the processes in action. An alternative to an extended case study or investigation might be the use of one or more written essay-type questions. However, this approach is likely to be less effective in bringing the topic to life.

To achieve P1, evidence should focus on design strategy, design tools (for example, schematic capture and auto-routing PCB CAD), creating and modifying schematic diagrams (for example, exchanging logic functions), design verification and design rule checking for both tracking and component layout.

It is important that learners demonstrate that they understand the additional processes required to produce multi-layer boards and that they appreciate the need for this type of board in conjunction with more complex electronic circuits. For example, circuits where microprocessor bus systems are realised on different layers or where power and ground connections are separated from signal tracks.

For P2, learners should describe typical production methods used in the manufacture of both single and multi-layer types of printed circuit board for electronic circuits of different complexity.

The explanation of the use of CAD software required for P3 should normally be based on the use of a SPICE package to verify a circuit design before it is manufactured.

For P4, learners should explain the need for thermal analysis and effective heat dissipation in terms of the total power dissipated and the maximum junction temperature ratings for the semiconductor device(s) present. They should explain that the requirements are satisfied by means of appropriately designed heat dissipaters on which the semiconductor devices are mounted.

To satisfy P5, learners should provide a written or verbal presentation of the use of surface mount technology (SMT) in the manufacture of electronic circuits. Learners should state the advantages and disadvantages of SMT and surface mounted devices (SMD) and should describe the typical outlines and packages used for SMD.

For P6, learners should explain the typical methods used for the manufacture of electronic circuits using SMDs. Note that learners are not expected to know how SMDs themselves are manufactured.

For P7, learners should design, manufacture and test a prototype printed circuit board for a given electronic circuit, to a valid standard. The electronic circuit should be supplied, complete with a full component list and component supplier’s references. Learners will be able to use these to determine physical constraints such as lead diameter, pin spacing and package outlines as well as any specialised mounting requirements such as the fitting of a heat dissipater. The circuits chosen should use no more than four active devices (for example transistors, diodes and conventional dual in-line (DIL) packaged integrated circuits) and associated passive components (for example PCB mounted resistors, capacitors, inductors, and transformers). The circuit should have an identifiable function and should be capable of functional testing without specialised equipment.
In order to carry out this task, learners should be supplied with a simple test specification based on test-point voltages, output signal levels etc. Centres are encouraged to provide learners with a standard test-jig in order to carry out these functional checks.

Typical examples of circuits that learners might develop include:

- a variable pulse generator (based on two 555 timers)
- a function generator (based on a single integrated circuit waveform generator)
- an audio amplifier (based on a complementary symmetrical output stage with driver and pre-amplifier stage)
- a regulated power supply (based on a bridge rectifier and a three-terminal fixed voltage regulator).

Note that these last two examples could require learners to undertake some thermal analysis and incorporate appropriate arrangements for heat dissipation (extending the work required for P4 and providing a basis for developing evidence for D1).

Evidence for M1 could be gathered through a written assignment or formal written test. M2 could be assessed through appropriately designed practical activities. M3 could be achieved by carrying out problems related to a case study and M4 by means of an assignment in which learners investigate modern industrial processes used for the high-volume manufacture of electronic circuits. For M5, learners should gather evidence through the evaluation of the design and manufacture of a Prototype PCB and create a written report that includes recommendations.

Learners can achieve D1 by means of an extended assignment involving thermal analysis and the design of a heat dissipator (for example, a heatsink for fitting to a three-terminal integrated circuit voltage regulator).

For D2, the exercise carried out to satisfy P7 could be developed further as learners evaluate their designs and make appropriate recommendations for mass production (based on the understanding that they have evidenced in relation to P1 and P2).

These recommendations will typically include size reduction (including the use of miniaturised or equivalent surface mounted components), the use of multi-layer boards and the use of appropriate interconnecting technologies (for example the use of multi-pole insulation displacement connectors (IDCs) fitted with PCB headers).
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1</td>
<td>PCB Design and Manufacturing Techniques</td>
<td>Learners investigate the techniques and processes used in the design and manufacture of PCB (including manufacture of both single and multilayer PCB as well as both manual and automated component assembly).</td>
<td>A report containing written responses, including, where appropriate, sketches that describe and explain the techniques and processes used in the design and manufacture of PCB.</td>
</tr>
<tr>
<td>P3, M2</td>
<td>Circuit Simulation and Analysis Using SPICE</td>
<td>Learners investigate and use simulation programs with integrated circuit emphasis (SPICE) to carry out a DC and small-signal AC analysis of a simple electronic circuit (e.g. a single stage amplifier with given circuit data, component values and SPICE models).</td>
<td>A report containing written responses, including, where appropriate, sketches that describe and explain the use of CAD software in the analysis of a simple electronic circuit prior to manufacture. Learners should include evidence of their use of a SPICE package to carry out a DC and small-signal AC analysis in the form of screen grabs and/or hard copies of the results obtained.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
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<tr>
<td>P4, M3, D1</td>
<td>Thermal Analysis and the Design of Heat Dissipaters</td>
<td>Learners investigate thermal analysis techniques and use them to design an effective heat dissipater for an electronic device (e.g. a TO3 or TAB encapsulated transistor, voltage regulator or other integrated circuit for which electrical and thermal data is supplied).</td>
<td>A report containing written responses, including, where appropriate, sketches that describe and explain the use of heat dissipaters. Learners should include evidence of their thermal analysis including the use of appropriate formulae and relevant calculations of thermal resistance, junction and surface temperature.</td>
</tr>
<tr>
<td>P5, P6, M4</td>
<td>Surface Mounting Technology</td>
<td>Learners investigate the use of surface mounting technology (SMT) and surface mounted devices (SMD).</td>
<td>A report containing written responses including, where appropriate, sketches of SMT packages and mounting arrangements.</td>
</tr>
<tr>
<td>P7, M5, D2</td>
<td>Design, Manufacture, Assembly and Testing of a Prototype PCB</td>
<td>Learners will design, manufacture and test a prototype electronic circuit. In order to complete this task they will need to design and produce a PCB. The PCB layout should be produced using computer aided design techniques.</td>
<td>A process portfolio containing a circuit diagram, detailed component list, sketches, notes, screen dumps, component and PCB track layout diagrams, test voltages and currents, waveform sketches (as appropriate) together with learners’ final prototype electronic circuit. The portfolio should include an evaluation of the design and manufacture of the electronic circuit together with an appropriate set of recommendations for its mass production.</td>
</tr>
</tbody>
</table>
Essential resources

Learners will need access to an electronics workshop with a range of electronic manufacturing equipment sufficient to meet the needs of the grading criteria (for example developing tanks, heated etching baths, PCB drilling equipment, soldering and wiring equipment). Centres will need to provide sufficient electronic test equipment to confirm the functionality of printed circuit boards and provide access to PCs equipped with PCB CAD and SPICE simulation packages. Learners will also need to be provided with relevant personal protective equipment (for example goggles, gloves, protective clothing) when manufacturing circuit boards, handling chemicals, soldering etc.

Indicative reading for learners

Textbooks


Websites

Electronic component suppliers and parts catalogues

Greenweld – www.greenweld.co.uk
Magenta – www.magenta2000.co.uk
Maplin Electronics – www.maplin.co.uk
Quasar Electronics – www.quasarelectronics.com

Electronic CAD, PCB design and SPICE resources

5Spice Analysis – www.5spice.com
Electronics Workbench Multisim – www.electronicsworkbench.com
Matrix Multimedia – www.matrixmultimedia.co.uk
WinSpice – www.winspice.com
Unit 33: Principles and Applications of Electronic Devices and Circuits

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Electronics and electronic devices are used in a huge variety of manufactured products. From everyday popular items such as cameras and thermometers to the robotic welding machines used in industry, the use of electronics is continually growing.

This unit provides a practical introduction to basic electronic devices along with analogue and digital electronic principles. It gives learners an opportunity to investigate the operation of diodes and transistors, two of the most important building blocks in electronic circuits. Learners will then go on to build and test circuits that make use of these devices and will consider the operation of integrated circuits such as the operational amplifier. Logic gates and flip-flops are also investigated both in practice and by using simple electronic principles, such as voltage gain or truth tables.

Finally, the unit will introduce learners to computer-based circuit design and simulation software packages that will allow them to build and test analogue and digital circuits. This will enable learners to recognise the importance of simulation software in the design of electronic circuits.

The overall aim of this unit is to build learners’ confidence in their ability to construct and test simple electronic circuits. The emphasis is on prototyping, constructing and measuring. The unit treats systems in terms of their functionality and their input/output relationships.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand the function and operation of diodes, transistors and logic gates
2. Be able to build and test operational amplifier-based analogue circuits
3. Be able to build and test combinational and sequential logic circuits
4. Be able to use computer-based simulation software packages to construct and test the operation of analogue and digital circuits.
Unit content

1 Understand the function and operation of diodes, transistors and logic gates

Diodes: types, e.g. Zener, light-emitting diode (LED), PN-junction; circuit applications, e.g. voltage stabiliser, indicator light, half-wave rectifier

Transistors: types, e.g. NPN, PNP or field-effect transistor (FET); analogue circuit (single-stage amplifier); digital circuit, e.g. comparator, transistor as a switch (automatic vehicle head lights or night light); operation, e.g. analogue (voltage gain, phase inversion), digital (set-point of operation); function of components in circuits

Logic gates: types of gates, e.g. AND, OR, NOT, NAND, NOR, XOR; gate symbols e.g. British Standards (BS), International Electrotechnical Commission (IEC), American National Standards Institute (ANSI); truth tables; Boolean expressions e.g. A+B, Ā, A • B

2 Be able to build and test operational amplifier-based analogue circuits

Building analogue circuits: method of construction e.g. prototype/bread-board, printed circuit, strip-board; types of circuits, e.g. oscillator, filter circuit, comparator circuit, inverting and/or non-inverting amplifier

Testing analogue circuits: performance against given design requirement; recording actual input and output voltages (tabulating data, plotting graph of results); circuit measurements, e.g. measurement of resonant frequency, cut-off frequency, switching point, gain at mid-frequency, bandwidth

3 Be able to build and test combinational and sequential logic circuits

Building combinational and sequential logic circuits: types of combinational circuit, e.g. at least three gates and three input variables; types of sequential circuit, e.g. R-S bi-stables, JK bi-stable, 3-stage counter, 3-stage shift-register based on JK or D-type bi-stables; types of logic family, e.g. transistor-transistor logic (TTL) and complementary metal oxide semiconductor (CMOS); characteristics of chips, e.g. supply voltage, input and output operating voltages, input and output impedance, propagation delay, power

Testing of logic circuits: records of performance against given design requirement; input and output states; use of truth tables; use of test equipment, e.g. logic probe, signature analyser

Minimisation of logic circuits: e.g. use of De-Morgan’s theorem; Karnaugh maps

4 Be able to use computer-based simulation software packages to construct and test the operation of analogue and digital circuits

Simulation of analogue circuit: types of circuits, e.g. transistor amplifier, op-amp, active filter, rectifier; types of components, e.g. resistor, capacitor, transistor, diode; instrument simulation, e.g. voltmeter, ammeter, oscilloscope; records of performance against given design requirement, e.g. screen print, input/output waveforms (with scales), gain-frequency response

Simulation of digital circuit: types of circuit, e.g. three input combinational circuit, counter, shift register; types of gates/sequential circuit, e.g. R-S bi-stables, JK bi-stable, 3-stage counter, 3-stage shift-register based on JK or D-type bi-stables; instrument simulation e.g. on/off indicator, logic probe, word generator, logic analyser; records of performance against given design requirement, e.g. screen print, digital input/output waveforms (with scales)
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td>P1</td>
<td><strong>explain the function of different types of diodes, transistors and logic gates in different electronic circuit applications</strong></td>
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<tr>
<td>P2</td>
<td><strong>explain the operation of two different types of transistor, one in an analogue and one in a digital circuit</strong></td>
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<tr>
<td>P3</td>
<td><strong>build two different types of analogue circuit using operational amplifiers, testing appropriately</strong></td>
<td><strong>M1 modify an existing analogue circuit to achieve a given revised specification by selecting and changing the value of one of the components</strong></td>
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<tr>
<td>P4</td>
<td><strong>explain the operation of three different logic gates with appropriate gate symbols, truth tables and Boolean expressions</strong></td>
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<tr>
<td>P5</td>
<td><strong>build a combinational logic circuit that has three input variables, testing appropriately</strong></td>
<td><strong>M2 modify a digital circuit to achieve a given revised specification by selecting and changing up to two logic gates</strong></td>
<td><strong>D1 compare and contrast two different types of logic circuits, referencing five key characteristics</strong></td>
</tr>
<tr>
<td>Assessment and grading criteria</td>
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<td><strong>P6</strong> build a sequential circuit using integrated circuit(s), testing its efficiency</td>
<td><strong>M3</strong> minimise a three input variables combinational logic circuit containing three gates</td>
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</tr>
<tr>
<td><strong>P7</strong> use a computer software package to simulate the construction and testing of an analogue circuit with three different types of components</td>
<td><strong>M4</strong> explain the benefits and limitations of a computer software package used to simulate the construction and testing of both analogue and digital circuits.</td>
<td><strong>D2</strong> analyse the effects of changing the values of circuit parameters on the performance of an analogue circuit containing transistors.</td>
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</tr>
<tr>
<td><strong>P8</strong> use a computer software package to simulate the construction and testing of a digital logic circuit with three gates.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

The learning outcomes and related criteria can be assessed in any order. The criteria P1, P2 and P3 are related and it would make sense to build a practical assignment or project around them. The focus would be to build two different types of analogue circuit (P3) that would allow learners to explain the operation of two different types of diodes, transistors and logic gates (P1) and the operation of one of the two different types of transistor (P2). Learners would then need to work on another circuit or simply explain the operation of a transistor in a digital circuit.

A second assignment could be used to cover the practical work required for P5 and P6. This could be linked to the explanation of theory that is necessary to achieve P4.

The last two pass criteria, P7 and P8, could be covered by a third assignment, either before the build and test exercise to prove the circuits, or afterwards, to simulate the circuit performance and testing that learners have already experienced.

Opportunities for the achievement of the merit criteria can be set within the assignments suggested above. For example, a task could be set for M1 that requires learners to modify a circuit to produce a different voltage gain from the one used in P3, or for a different resonant frequency for an oscillator.

M2 could be obtained through a task additional to that used for P5, such as to modify the circuit given for P5. M3 simply requires a minimisation (for example using a Karnaugh map). M4 could then be completed as this requires an explanation of the benefits and limitations of a computer software package, essentially encompassing P7 and P8.

To achieve D1, learners need to compare and contrast two different types of logic family, with reference to at least five characteristics. The comparison, which can be partly but not wholly achieved using a table, should consider common logic families such as TTL and CMOS. Where a table is used for comparison, it is expected that the meaning of any terms used (for example sink current) should be clearly explained. The comparison as a whole (table, written explanations, diagrams etc.) must make it clear how one logic family can be differentiated from another.

D2 requires an analysis, using a simulation package, of the effects on the performance of an analogue circuit containing transistors of changing the values of circuit parameters (for example components or component values, input/output voltages or signals). To meet the criterion it would require at least one other parameter to be changed – possibly the supply voltage, or input voltage – and noting how ‘clipping’ can occur. Part of the analysis could be to use calculations to show how the theoretical results align with those actually obtained through simulation.

Again, careful selection of the circuits used for the pass/merit assignment could enable this final step to be a natural development from the work already carried out. Establishing firm links between the pass, merit and distinction criteria in this way will encourage learners to work towards higher levels of achievement and will improve the relevance and coherence of the assessment activities.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
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<tr>
<th>Criteria covered</th>
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<th>Scenario</th>
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</tr>
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<tbody>
<tr>
<td>P1, P2, P3, M1</td>
<td>Construction and Operation of Analogue Circuits</td>
<td>Learners have been asked by their employer to build and test analogue circuits to meet a new design requirement.</td>
<td>A practical assignment accompanied by written tasks/oral questioning in which learners construct and test two different analogue circuits, each circuit containing a diode and one containing a transistor. One of the circuits could then be modified to meet a revised specification. Additional tasks would then require the learner to explain the purpose/operation of the diodes and transistor, plus an additional transistor from a further digital circuit.</td>
</tr>
<tr>
<td>P4, P5, P6, M2, M3, D1</td>
<td>Construction and Operation of Logic Circuits</td>
<td>Learners have been asked by their employer to build and test logic circuits to meet a new design requirement.</td>
<td>A practical assignment accompanied by written tasks/oral questioning, in which learners construct and test combinational and sequential circuits. Additional tasks would then require the learner to explain the operation of logic gates and compare and contrast different types of logic family.</td>
</tr>
<tr>
<td>P7, P8, M4, D2</td>
<td>Using Simulation Software to Construct and Test Circuits</td>
<td>Learners have been asked by their employer to use software to simulate the construction and testing of circuits to meet a new design requirement.</td>
<td>A practical assignment in which learners construct and test analogue and digital circuits using simulation software. They should also be given the opportunity to analyse the effect of changing circuit parameter values.</td>
</tr>
</tbody>
</table>
Essential resources

Centres will need to provide access to an appropriate electronics laboratory with a range of measuring and test equipment, as listed in the unit content. For example, facilities for circuit construction and prototyping, a range of components, logic-tutor boards, hardware and software to support computer-based analogue and digital schematic capture and circuit simulation will be needed. Learners will also need access to publications, reference data and manufacturers’ product information to enable them to consider the different types of components listed within the unit.

Indicative reading for learners

Textbooks


Unit 34: Engineering Maintenance Procedures and Techniques

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

The correct maintenance of engineering systems results in improved efficiency and can save organisations time and money in relation to system downtime and stoppages in production. This unit introduces learners to a range of commonly used engineering maintenance procedures and monitoring techniques, which may be encountered in any manufacturing, plant or process environment. The unit will also help learners understand how the data gathered from monitoring engineering systems can be used.

Learners will examine the consequences of maintenance and maintenance planning in terms of cost, and the implications for production, personnel, the environment and safety. They will gain an understanding of engineering maintenance and process planning and develop the skills needed to plan scheduled and preventative maintenance activities on engineering systems.

The unit has been designed to reflect the multidisciplinary nature of maintaining manufacturing plant and process engineering systems, rather than being confined to specialist knowledge of a single discipline. Learners will need to produce a maintenance plan for an engineering system involving two or more interactive technologies from mechanical, electrical, fluid power, process control or environmental systems.

Learners will be required to know about the methods, procedures and documentation that must be completed before handing over maintained systems, and how to confirm that the system is ready to run in a safe and operable condition.

Finally, learners will gain an understanding of the basic techniques of condition monitoring and how computerised maintenance systems can be used to capture data and predict specific failure trends in plant, machinery, equipment and systems.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Know about the types of maintenance associated with engineering plant, equipment and systems
2. Know about maintenance frequency, the cost of maintenance and its effects on production
3. Be able to produce a maintenance plan for a specific engineering system
4. Understand how data gathered from monitoring the performance and condition of engineering plant, equipment and systems can be used.
Unit content

1 Know about the types of maintenance associated with engineering plant, equipment and systems

Type of maintenance: types, e.g. planned, total preventative maintenance (TPM), breakdown, scheduled, corrective, emergency, post fault, scheduled servicing, modification to equipment, condition-based maintenance; maintenance activities, e.g. visual examination, monitoring, replacement, sensory, testing, checking alignment, making routine adjustments, removing excess dirt and grime, recording results and reporting defects

Reasons for maintenance: issues relating to higher plant reliability and availability, e.g. longer equipment life, improved product quality, greater cost effectiveness, improved safety, legal requirements; issues relating to health and safety, e.g. statutory regulations and standards, company rules, codes of conduct, reduction in environmental damage

Engineering systems, plant and equipment: systems, e.g. process monitoring and control, mechanical, fluid power, electrical, process control, environmental systems (such as fume extraction or air conditioning), medical; plant and equipment, e.g. gearboxes, pumps, engines, compressors, machine tools, lifting and handling equipment, process control valves, mechanical structures, company specific equipment, electrical plant, motors, starters, switchgear and distribution panels, cardiovascular equipment, medical imaging equipment

2 Know about maintenance frequency, the cost of maintenance and its effects on production

Frequency of maintenance: time, e.g. daily/weekly/monthly/yearly; activities, e.g. data logging and checking, adjustments, tests, routine maintenance, fixed-interval overhaul, equipment replacement, use of computerised techniques; methods for determining frequency, e.g. calendar maintenance, hours run meter

Costs: representative data of cost, e.g. maintenance as a proportion of total expenditure, utilisation of operator (frontline maintenance), maintenance labour, maintenance contracting, lost production, levels of spares and consumables in stores, equipment hire/replacement, safety and environmental effects

Effects on production: e.g. downtime, effects on operating performance, product quality, customer service, financial penalties, effects on associated equipment or plant, higher energy costs, secondary damage
3 Be able to produce a maintenance plan for a specific engineering system

*Maintenance plan:* maintenance planning, e.g. methods, sequence and timing, frequency, check lists, planned repairs, use of planning techniques, Gantt and Pert charts, team working, computerised methods; resources, e.g. personnel, supporting equipment, tools, manuals, materials, components, facilities, stores spares and consumables; procedures e.g. safety procedures, risk assessment, Control of Substances Hazardous to Health (COSHH) Regulations 2002 and other relevant safety regulations, safe access and working arrangements for the maintenance area, isolation requirements for plant/equipment, disposal of waste, handover procedures, liaison with other departments

*Engineering systems:* process monitoring and control, e.g. mechanical, fluid power, electrical, process control, environmental systems (such as fume extraction or air conditioning), medical (such as cardiovascular, anaesthetic and ventilation, medical imaging)

*Supporting documentation:* manufacturers’ drawings and maintenance documentation; maintenance logs, databases, records, results and defect reports; plans and schedules; production records; standing instructions; handover documentation

4 Understand how data gathered from monitoring the performance and condition of engineering plant, equipment and systems can be used

*Monitoring techniques:* e.g. condition monitoring, scheduled overhauls, routine servicing, planning systems, hazard studies, failure mode and effect analysis (FMEA), teamwork, self-diagnostic and computerised systems

*Data collection:* collected at identified points; data, e.g. types, operational characteristics, output quality, throughput, environmental operating conditions; interpreting data, e.g. electronic-based data, data recording and presentation

*Need for monitoring:* physical aspects, e.g. improve safety, reduce environmental hazards, extend equipment life, ensure accurate equipment performance; cost-related aspects, e.g. improve product quality, reduce downtime, reduce costs; other aspects, e.g. produce comprehensive computer database, better communications
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong> describe two types of maintenance</td>
<td><strong>M1</strong> justify the suitability of particular types of maintenance for specific applications</td>
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<tr>
<td><strong>P2</strong> describe the reasons for maintaining a specified engineering system</td>
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<tr>
<td><strong>P3</strong> describe four maintenance activities for a specified engineering system</td>
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<tr>
<td><strong>P4</strong> identify two items of plant and equipment for a specified engineering system that require maintenance, describing the frequency at which it should be carried out</td>
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<tr>
<td><strong>P5</strong> describe the effects on production of carrying out maintenance on a specified engineering system</td>
<td><strong>M2</strong> from a given range of data, calculate the maintenance costs for a specified engineering system in relation to maintenance type, resources and production downtime</td>
<td><strong>D1</strong> discuss how the frequency of maintenance affects production and costs for a specified engineering system</td>
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<tr>
<td>Assessment and grading criteria</td>
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</tr>
<tr>
<td>P6 produce a basic maintenance plan for a specified engineering system containing supporting documentation with resource and procedure requirements</td>
<td>M3 justify planned maintenance for a specified engineered system in terms of system downtime, environmental and health and safety considerations</td>
<td>D2 produce a comprehensive plan for the maintenance of a specified engineered system containing all supporting documentation.</td>
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<tr>
<td>P7 describe an application of monitoring, the technique used and how the data is collected and interpreted</td>
<td>M4 analyse given condition monitoring and quality control data to predict specific machinery/plant failure.</td>
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<tr>
<td>P8 explain the need to monitor the performance and condition of engineering systems.</td>
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</table>
Essential guidance for tutors

Assessment

Evidence of achievement could be obtained from investigative assignments, reports of workshop activities or through learners building a portfolio from maintenance operations carried out in the workplace.

The unit could be assessed through a mixture of written assignments and practical tasks. Assuming that the learning outcomes are delivered in order, a first assignment with a series of written tasks could be used to cover the criteria associated with learning outcomes 1 and 2. The first task could ask learners to describe two types of maintenance (P1) and four maintenance activities (P3). Learners would then need to describe the need for maintaining a specific engineering system (P2). The system might be mechanical, fluid power, electrical, process control, or an environmental system. This could be extended to cover M1, for which learners must justify the suitability of particular types of maintenance for specific applications. The work produced for M1 should include total preventative maintenance (TPM), scheduled or condition-based maintenance.

A second assignment to cover P4 could ask learners to identify items of plant and equipment that require maintenance and the frequency at which maintenance should be carried out. They will also need to give reasons for carrying out maintenance, for example longer equipment life, improved product quality, greater cost effectiveness, improved safety or legal requirements. The task also needs to ensure that learners cover timing, activities carried out and methods of determining the frequency. It should also ensure that learners have opportunities to give reasons for the required maintenance covering plant reliability/availability and issues relating to health and safety.

A third assignment covering P5 and M2 and D1 could ask learners to calculate from given data the cost of maintenance and describe the effects on production. A further task requiring learners to explain how the frequency of maintenance can affect production and cost would enable M2 to be met.

A well-planned, investigative practical assignment could be used to cover criteria P6, M3 and D2. To achieve P6, learners need to produce a basic maintenance plan for a specified system with accompanying documentation with resource and procedure requirements.

This basic maintenance plan should include at least the following:

- identification of the plant/equipment/machinery to be maintained
- identification of the person with overall responsibility for the maintenance process
- the maintenance procedures to be adopted
- timescales for preparation and implementation of the maintenance activities
- a list of the physical resources required for the maintenance activities (for example lifting equipment, tools, test and measuring equipment)
- details of the administrative support that is to be provided for the maintenance work
- details of the maintenance documentation systems to be provided.
This then needs to be built on in order to achieve D2, where a comprehensive maintenance plan containing all supporting documentation needs to be produced for a specified engineering system. The comprehensive maintenance plan should contain the entire basic plan together with at least the following:

- health and safety procedures
- identification of appropriate types of maintenance compatible with production requirements
- identification of who is to carry out the maintenance (for example in-house labour, contractors, specialists)
- lists of sub-assemblies and spare parts to be held
- the quality control procedures that need to be followed during maintenance activities, together with maintenance tools/equipment control and test instrument calibration
- environmental considerations such as the procedures to be adopted for the disposal of all types of waste material arising from the maintenance activity including the safe disposal of toxic and/or hazardous materials if relevant
- handover documentation.

To achieve M3, the practical activity could be supported by written evidence, showing that learners are able to justify the maintenance plan in terms of system downtime, environmental and health and safety considerations.

The criteria associated with learning outcome 4 could be assessed through a written assignment. Learners need to explain the need for monitoring the performance and condition of engineering systems (P8). This should include the physical aspects, cost related aspects and other aspects as outlined in the unit content. Systems do not need to be given as the task should be tackled as a generic response outlining the need in systems in general. The task also needs to ask learners to describe an application of monitoring, the technique used and how data is collected and interpreted (P7).

To achieve M4, learners need to carry out an in-depth analysis of given condition monitoring and quality control data to predict specific machinery/plant failure. An example would be data produced by vibration analysis for a large motor bearing. The data could come from computer analysers, inspection and test, SPC (Statistical Process Control), or from general product quality control.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, M1</td>
<td>Types of Maintenance Activities</td>
<td>Learners need to report to their manager on types of maintenance and maintenance activities and justify particular reasons for maintenance.</td>
<td>A written report relating general maintenance types to specific examples.</td>
</tr>
<tr>
<td>P4</td>
<td>Maintenance Needs in a Complex Engineering System</td>
<td>Learners need to write a report on the maintenance of a complex engineering system.</td>
<td>A written report describing the practical needs for maintenance of plant and equipment that also discusses frequency that maintenance is carried out.</td>
</tr>
<tr>
<td>P5, M2, D1</td>
<td>Costing a Maintenance Schedule</td>
<td>Using plant data and a maintenance schedule, learners calculate the cost and effect of maintenance on system production.</td>
<td>A written assessment of the plant maintenance data to identify the costs of maintenance and its impact on production and cost.</td>
</tr>
<tr>
<td>Criteria covered</td>
<td>Assignment title</td>
<td>Scenario</td>
<td>Assessment method</td>
</tr>
<tr>
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<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>P6, M3, D2</td>
<td>Maintenance Planning</td>
<td>Learners produce a maintenance plan and justify the maintenance programme.</td>
<td>An investigative practical assignment. Evidence includes a written basic maintenance plan for the specified system with accompanying documentation, and resource and procedure requirements. A comprehensive maintenance plan containing all supporting documentation for the specified engineering system. Additional written evidence justifying the maintenance plan in terms of system downtime, environmental and health and safety considerations.</td>
</tr>
</tbody>
</table>
Criteria covered | Assignment title | Scenario | Assessment method
--- | --- | --- | ---
P7, P8, M4 | Monitoring Techniques | Learners need to describe condition monitoring and how data is used to a new member of staff. | Written explanation of the need for monitoring the performance and condition of engineering systems.
 |  |  | Written or oral description of an application of monitoring, the technique used and how data is collected and interpreted.
 |  |  | Written analysis of given condition monitoring and quality control data to predict specific machinery/plant failure.

Essential resources

In order to deliver this unit, centres will need to provide learners with access to complex engineered systems or test rigs, relevant data books, manufacturers’ specifications, system manuals, functional flow charts and system diagrams. Learners will also need appropriate test equipment and tools and access to maintenance records/documentation from modern factories/plant. Computer software for data logging and self-diagnostics should also be provided.

Indicative reading for learners

Textbooks


Unit 35: Monitoring and Fault Diagnosis of Engineering Systems

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Condition monitoring and quality control techniques are used to detect potential failure symptoms in engineering systems. The methods used by engineering technicians range from fully automated monitoring down to the use of the human senses. This unit gives learners an understanding of the fundamentals of engineering system monitoring and fault diagnosis, and explains the basic concepts of condition monitoring. The unit examines the development of engineering system monitoring and fault diagnosis and how modern technology, quality control and environmental issues have affected current thinking.

The unit will give learners an understanding of the precautions required to protect themselves and others in the workplace, and focuses on the safety measures needed when carrying out monitoring activities, especially those for isolating equipment.

Learners will understand how to use a range of condition monitoring equipment and will develop the skills and knowledge required for the location and identification of faults in engineering systems. Learners will be required to select the appropriate monitoring technique and equipment based on the type of plant or equipment being monitored and the conditions checked.

The unit will enable learners to check and set up monitoring equipment before using it to carry out diagnostic condition monitoring on engineering systems, in accordance with approved procedures. Learners will be expected to use a variety of fault diagnosis methods and techniques, and use a number of diagnostic aids and equipment. From the evidence gained they will then identify the fault and its probable cause.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Know the health and safety requirements relevant to monitoring and fault diagnosis of engineering systems
2. Know about system monitoring and reliability
3. Be able to use monitoring and test equipment
4. Be able to carry out fault diagnosis on engineering systems.
Unit content

1 Know the health and safety requirements relevant to monitoring and fault diagnosis of engineering systems

Legislation: appropriate statutory acts and regulations e.g. Health and Safety at Work etc. Act 1974, Management of Health and Safety Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER) 1998, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013, Lifting Operations and Lifting Equipment Regulations (LOLER) 1998, Manual Handling Operations Regulations (MHOR) 1992, Personal Protective Equipment (PPE) at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Control of Noise at Work Regulations 2005, Health and Safety (First-Aid) Regulations 1981; specific safety requirements, e.g. company rules, permit to work procedures, risk assessment, environmental issues; health and safety procedures e.g. response to alarms, use of safety equipment, reporting of accidents, reporting of hazardous items of plant or equipment; personal safety, e.g. appropriate dress, protective clothing, appropriate or protective headgear, protective gloves and footwear, eye protection, face masks and respirators, appropriate use of barrier creams, personal cleanliness, prompt attention to injuries

Hazards and practices: workplace hazards, e.g. compressed air, hydraulic fluid, gases, hot surfaces, electrical equipment, unfenced machinery, toxic substances and fumes, falling objects, liquid spillage, untidy work area, badly maintained tools and test equipment; safe working practices, e.g. isolation procedures, methods of immobilising equipment, precautions to be observed when operating or working on live equipment, permit to work, use of danger tags, warning notices, safety barriers, cones and tapes

Engineering systems: process monitoring and control; fault diagnosis; systems, e.g. mechanical, fluid power, electrical, process control, environmental systems (such as fume extraction or air conditioning), medical (such as cardiovascular, anaesthetic and ventilation, medical imaging)

2 Know about system monitoring and reliability

Monitoring terminology: condition monitoring methods, e.g. offline portable monitoring, sampled monitoring, continuous monitoring, protection monitoring, human sensory monitoring; monitoring techniques, e.g. vibration analysis, temperature analysis, flow analysis, particle analysis, crack detection, leak detection, pressure analysis, voltage/current analysis, thickness analysis, oil analysis, corrosion detection, environmental pollutant analysis

Failure and reliability: calculations concerning failure, e.g. degrees and causes of failure, failure rate, failure modes, functional failure, primary and secondary functions, mean time between failures (MTBF), reliability; factors affecting reliability, e.g. design, operation, environment and manufacture, reduction in system/device failure, e.g. routine servicing, adjustments; data, e.g. defects examination, statistical process control (SPC), quality
3 Be able to use monitoring and test equipment

*Monitoring and test equipment*: use of fixed and portable monitoring equipment for on and offline monitoring including continuous and semi-continuous data recording e.g. vibration monitoring of bearings, self-diagnostics (such as PLCs/smart sensors, computerised data acquisition, data logging, electrical data, gas analysis); use of handheld instruments, e.g. meters, thermal imaging; test equipment for taking measurements of parameters, e.g. temperature, pressure, viscosity, speed, flow, voltage, current, resistance, sound, vibration

*Procedures*: practical methods, e.g. crack detection, leak detection, corrosion detection, flow analysis, vibration analysis, pressure analysis

4 Be able to carry out fault diagnosis on engineering systems

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

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

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>To achieve a pass grade the evidence must show that the learner is able to:</td>
</tr>
<tr>
<td><strong>P1</strong> outline the aspects of health and safety legislation that apply to monitoring and fault diagnosis of an engineering system</td>
</tr>
<tr>
<td><strong>P2</strong> describe workplace hazards and safe working practices relevant to specific monitoring and fault diagnosis situations</td>
</tr>
<tr>
<td><strong>P3</strong> describe a condition monitoring method and technique related to a given engineering system</td>
</tr>
<tr>
<td><strong>P4</strong> use given data to calculate failure rates for a range of components and equipment</td>
</tr>
<tr>
<td><strong>P5</strong> describe the factors affecting reliability for a given engineering system</td>
</tr>
<tr>
<td>Assessment and grading criteria</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td><strong>P6</strong> describe the monitoring and test equipment used for measuring given system condition parameters</td>
</tr>
<tr>
<td><strong>P7</strong> use procedures to carry out system monitoring on two separate engineering systems</td>
</tr>
<tr>
<td><strong>P8</strong> describe the terms and two different techniques related to fault diagnosis</td>
</tr>
<tr>
<td><strong>P9</strong> use diagnostic techniques, test and measuring equipment and aids to locate faults on two separate engineering systems where two malfunction symptoms are evident on each system.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Evidence of achievement of the learning outcomes and grading criteria may be obtained from well-planned investigative assignments or reports of workshop activities. Alternatively, it may be accumulated by learners building a portfolio from investigations and monitoring and fault diagnosis operations in the workplace or through realistic exercises and tests. In either case, the opportunity should exist for merit and distinction grades to be achieved with relevant and sufficient evidence to justify the grade awarded.

Assuming that the unit is delivered in the same order as the learning outcomes, a first assignment could cover the criteria for learning outcome 1 (P1 and P2). This assignment could be a written or practical task requiring learners to identify appropriate health and safety procedures and personal safety requirements for an engineering system. Such a system might be mechanical, fluid power, electrical, process control or an environmental system (such as fume extraction or air conditioning).

Learning outcome 2 could be assessed through a written or time-constrained assignment requiring learners to calculate, from given data, failure rates for a range of components and equipment. These could be pumps, actuators, compressors, air receivers, accumulators, valves, generators, motors, transformers, switch gear, machine tools, engines or gearboxes (P4). The assignment could contain a task requiring learners to describe factors affecting reliability (P5) and monitoring methods and techniques (P3). A third task could be added to cover M1, requiring learners to identify and describe four factors that influence either failure or reliability in a given engineering system. A further task requiring learners to identify and describe environmental conditions affecting the reliability of components in items of equipment and analyse the effects of the environment on component/asset reliability could enable achievement of M2 and D1. The range of components and equipment should be sufficient to allow these higher grading criteria to be achieved. However, the range required for pass criterion P4 would need to be at least one mechanical type, one electrical type and one fluid type system. Therefore, a range of data for each is required to be given to learners.

Assessment of learning outcome 3 could be by a well-planned practical investigative assignment covering criteria P6, P7 and M3. This would require learners to carry out monitoring activities on two separate engineering systems, such as bearing vibration analysis, temperature, flow, particle, oil, pressure, voltage/current corrosion, environmental pollutant, crack and leak detection. Such systems may be mechanical, fluid power, electrical, process control or environmental systems. This could be supported by written evidence that shows learners are able to describe the use of monitoring and test equipment and evaluate the quality of measurements and the limitations of given items of monitoring equipment. Witness statements and annotated photographs would be suitable evidence to support the use of procedures to carry out system monitoring.

Learning outcome 4 is best suited to practical investigation. For P8, learners need to explain the terms and two different techniques from those in the unit content, such as six-point, half-split, input-output, emergent problem sequence, functional testing, injection and sampling and unit substitution. For P9, they need to use diagnostic techniques, test and measuring equipment (such as dial test indicators, torque instruments, logic probes, multimeters etc.) and aids to locate faults on two separate engineering systems, where two malfunction symptoms are evident on each system.
The assignment to cover this could have a task requiring learners to carry out fault diagnosis on a given engineered system. This could be either in a simulated situation or in the workplace using evidence gathered in a logbook containing items such as equipment used, tests carried out and measurements taken. This should be supported by the inclusion of witness statements.

Learners must describe typical fault conditions and find faults independently on equipment, which exhibits symptoms of more than one function failure. For example, a pump can have two functions, one to pump water at a given rate, the other to be free of water leaks whilst pumping. To achieve M4, learners must demonstrate a logical approach to fault finding and be able to distinguish between symptoms, faults and causes. A second task supported by written evidence would enable learners to demonstrate that they are able to analyse data and use this information to predict/detect potential failures in given engineering systems for D2.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2</td>
<td>Health and Safety in System Monitoring and Fault-finding</td>
<td>An investigation of practical health and safety issues and legislation, relating to system monitoring and fault diagnosis.</td>
<td>A report and risk assessment, identifying and discussing relevant health and safety issues, including the methods used to address them.</td>
</tr>
<tr>
<td>P3, P4, P5, M1, M2, D1</td>
<td>System Condition Monitoring and Reliability</td>
<td>Practical and theoretical investigations into the factors affecting component and system reliability, including: failure rate calculations; factors affecting reliability and system and component monitoring techniques, in general and as applicable to a specified engineering system.</td>
<td>A written and/or time-constrained assignment containing learners’ calculations of failure rates for specified components and equipment; discussions on reliability; and on system monitoring methods. Supported by learners’ engineering sketches and diagrams.</td>
</tr>
<tr>
<td>P6, P7, M3</td>
<td>Performing System Monitoring and Measurements</td>
<td>A practical investigation into the monitoring and evaluation of two different engineering systems.</td>
<td>A report or portfolio of evidence and data describing the monitoring techniques and equipment used, and interpreting the measurements made on the two systems. Supported by learners’ engineering sketches and diagrams. Witness statements and annotated photographs.</td>
</tr>
<tr>
<td>Criteria covered</td>
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<td>Assessment method</td>
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</tr>
<tr>
<td>P8, P9, M4, D2</td>
<td>System Fault-Finding Techniques</td>
<td>A practical investigation into two different techniques across two separate systems (four tasks in total) using diagnostic techniques, test and measuring equipment and aids.</td>
<td>A report containing an explanation and evidence of the investigations and tests performed, and the conclusions drawn. Supported by learners’ engineering sketches and diagrams. Witness statements and annotated photographs.</td>
</tr>
</tbody>
</table>

**Essential resources**

This unit is intended to provide learners with a practical introduction to monitoring and fault diagnosis methods and techniques. Therefore, it is essential that learners have access to:

- actual engineered systems or test rigs designed for monitoring/fault finding
- data books and manufacturers’ specifications
- system manuals and functional flow charts and system diagrams
- computer software for data logging and self-diagnostics
- appropriate test equipment and tools
- maintenance records.

**Indicative reading for learners**

**Textbook**

ISBN 9781860583612

**Website**

Health and Safety Executive  
www.hse.gov.uk
Unit 36: Principles and Applications of Engineering Measurement Systems

Level: 3  
Unit type: Optional  
Assessment type: Internal  
Guided learning: 60

Unit introduction

There is now a wide range of systems and methods used to measure performance and operations in engineered systems.

This unit is designed to develop learners’ knowledge and understanding of the use of measurement and testing in engineered systems, while giving them opportunities to explore both traditional and modern methods. The unit explains the physical principles used in transducers and shows the way that these principles are exploited in practice across a range of industrial measurement applications.

The selection of correct measurement systems is key to the optimum performance and operation of an industrial plant. The unit gives learners an insight into the main elements of a measurement system and shows how these elements working together provide a required function.

The unit describes recording and display devices and their operational characteristics, so that learners will be able to use and make informed choices between similar devices on technical grounds. Modern display and recording techniques are discussed and learners’ are given the opportunity to use and design virtual instrumentation systems using computer software.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Understand the applications of common measurement systems
2. Understand the operation of measurement system components
3. Be able to use testing, recording and display equipment for a measurement application
4. Be able to test and calibrate a measuring system.
Unit content

1 Understand the applications of common measurement systems

Main purpose and elements of measurement: producing or obtaining data; carrying out inspection and testing; monitoring health and safety; checking outputs, e.g. meeting specifications, quality control, condition monitoring; controlling processes; carrying out statistical analysis

Measurement system elements: block diagrams; elements, e.g. transducers, signal conversions, signal conditioning, recording and display, transmission links; common measurement systems, e.g. pressure transmitter, level transmitter, temperature transmitter, flow transmitter

Measurement system performance: performance terms, e.g. accuracy, error, linearity, reliability, repeatability, sensitivity, resolution, range, transfer function, static and dynamic characteristics, electrical noise, calibration

2 Understand the operation of measurement system components

Transducer types: output of common measurement transducers, e.g. temperature, pressure, flow, level, vibration, weight, displacement; physical principles, e.g. resistive, capacitive, piezo-electric, inductive, opto-reflective, static pressure, elasticity

Signal converters: conversion process, e.g. voltage to current, pressure to current, current to pressure, frequency to voltage, analogue to digital (ADC), digital to analogue (DAC); signal converter types, e.g. Wheatstone bridge, V/I converter, P/I converter, I/P converter, F/V converter, ADC, DAC

Signal processors: types, e.g. voltage and current amplifiers, mechanical amplifiers, simple signal filters, multiplexers, decoders; specification requirements, e.g. voltage amplitude, current amplitude, signal frequency, noise reduction

3 Be able to use testing, recording and display equipment for a measurement application

Test equipment: electrical/mechanical types, e.g. multimeters, handheld oscilloscope, signal generator, logic testers, earth loop impedance meter, pressure injector, 4–20 mA loop calibrators, insulation tester, optical alignment; safety; functions and operation; specification, e.g. output, input, range of operation, resolution

Recording and display devices: computer elements in monitoring and recording, e.g. data acquisition, interface cards, software; specification, e.g. acquisition speed, resolution, input type; plotters and chart recorders

Virtual instrumentation: software available, e.g. NI LabVIEW, Visual Basic, Discovery; mimics; trending; alarms

4 Be able to test and calibrate a measuring system

Test and calibrate: calibration parameters (component specification, system requirements); calibration of measurement equipment, e.g. pressure, level, temperature, flow, nucelonic, position, speed

System specification and function: measurement system specifications; characteristics and limitations of measuring systems, e.g. operating range, environment
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>To achieve a pass grade the evidence must show that the learner is able to:</td>
</tr>
<tr>
<td><strong>P1</strong> explain the main purpose and elements of measurement</td>
</tr>
<tr>
<td><strong>P2</strong> explain the main elements in three given common measurement systems</td>
</tr>
<tr>
<td><strong>P3</strong> explain the performance of a given common measurement system</td>
</tr>
<tr>
<td><strong>P4</strong> explain the operational principles of three different types of transducer</td>
</tr>
<tr>
<td><strong>P5</strong> explain the conversion process that takes place in three given signal converters</td>
</tr>
<tr>
<td><strong>P6</strong> describe the signal processors needed to meet a given specification</td>
</tr>
<tr>
<td><strong>P7</strong> use appropriate test equipment to test the function and operation of a common measurement system against specification</td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P8</strong> use an appropriate recording or display device to meet a given specification</td>
<td><strong>M2</strong> design a graphic display for a given measurement system</td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> use virtual instrumentation software to display, record and generate a report on a given measurement system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P10</strong> test a given common measurement system to meet the requirements of the system specification, calibrating as required to ensure its performance limitations are not exceeded.</td>
<td><strong>M3</strong> explain the testing methods used and the calibration process.</td>
<td><strong>D2</strong> evaluate the performance limitations of the calibrated system.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment evidence for the first six pass criteria (P1–P6) could be produced through a written assignment. After explaining the various purposes of measurement systems (P1), learners could be asked to explain the main elements of three different measurement systems using block diagrams (P2), given manufacturers’ data sheets for each of the given systems.

The block diagram could provide learners with a basis to select and explain the functionality and performance of the transducer, signal converter and signal processor elements (P3, P4, P5 and P6). The assignment must include reference to common performance terminology.

A practical workshop assessment could be used to assess pass criteria P7 and P10. Firstly, learners could be given a measurement system and data sheets. They could then be given details of the required output tests that must be carried out to ensure it can be checked for function and operation. Learners will need to select an appropriate test instrument that meets the test requirements, and perform the test(s). A written report should be produced presenting the results clearly, with appropriate conclusions. A witness statement/observation record could be used to confirm the safe use of the test equipment for P7 and that testing and calibration was carried out successfully (P10). This could be extended to include a written explanation of the testing methods and calibration process (M3) and an evaluation of the performance limitations to achieve D2.

The final assessment could be a combined practical and written assignment that asks learners to use a computer with previously produced screen mimics and interfaces to record and display data from the output of a measurement system (P9). Learners could then be asked to compare this display/recording/trending system with alternatives, select an alternative and provide reasons for the selection (P8).

Assessment evidence for M1 is likely to be an extension to the assignment covering pass criteria P1–P6. Learners could be asked to design a new measurement system (block diagram form may be sensible) to meet a given measurement specification. The specification will need to include a transducer, a signal converter and a signal processor. This type of activity could be supported through simulation software to confirm that the specification has been met.

Assessment evidence for M2 could be achieved through an extension to the assignment covering criteria P8 and P9. Learners will need to be given a computer interfaced to the previous measurement system. They could then be asked to design a software graphic, input the measured data and display in an appropriate form to meet a given specification.

Assessment evidence for D1 could be achieved through an extension of the assignment covering criteria P1–P6 and M1. Learners could be asked to evaluate the performance of a measurement system that is measuring a variable within an industrial process plant. This evaluation will consider the operation and performance of the system. Learners could be asked to suggest improvements to the system or suggest an alternative, having identified and discussed advantages and limitations.
## Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
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<tr>
<th>Criteria covered</th>
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<th>Assessment method</th>
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</thead>
<tbody>
<tr>
<td>P1, P2, P3, P4, P5, P6, M1, D1</td>
<td>Measurement Systems and System Components</td>
<td>Learners need to produce an information booklet detailing the purpose of measurement and the function of the main elements in a measurement system.</td>
<td>A written assignment, including a task requiring learners to explain the purpose of measurement and a series of descriptions, based on block diagrams, of the main elements within a measurement system.</td>
</tr>
<tr>
<td>P7, P10, M3, D2</td>
<td>Testing and Calibrating Measurement Systems</td>
<td>Learners need to use suitable equipment to test and calibrate a measurement system.</td>
<td>A practical assignment supported by observation records and a written report in which learners select equipment, perform tests to meet requirements and calibrate a measurement system.</td>
</tr>
<tr>
<td>P8, P9, M2</td>
<td>Recording and Display Equipment</td>
<td>Learners need to record and display data from a measurement system and write a report comparing the system used with alternatives.</td>
<td>A mixed practical and written assignment. Learners are to use a computer with previously produced screen mimics and interfaces to record and display data from the output of a measurement system. They should then compare this display/recording/trending system with alternatives and select an alternative.</td>
</tr>
</tbody>
</table>
Essential resources

Process rigs and associated measurement and test equipment are essential for the delivery and assessment of much of this unit. Learners should have access to relevant workshop or laboratory facilities, including:

- process plant or system simulators
- measurement and data acquisition software
- measurement and data acquisition hardware (PCs and interface cards)
- data books and manufacturers’ specifications
- measurement and test equipment manuals
- appropriate tools.

Indicative reading for learners

Textbook

ISBN 9780750664325
Unit introduction

Electricity is used in a wide range of applications, such as manufacturing, healthcare, transport and entertainment. All of these are reliant on electrical technology in one form or another. For example, for someone to be able to visit a holiday destination, go to a music festival or download the latest track by their favourite performer, numerous electrical activities and concepts must be coordinated.

Electrical technology provides the link between science and its application. It is underpinned by a range of enabling technologies and concepts such as materials science, energy efficiency, environmental impact, geological characteristics and design.

This unit provides an introduction to ways in which electricity is produced, the options we have about how and why we produce it, and the disposal of related by-products. The unit considers how the electricity that has been produced is then moved to where the customer (end-user) needs it. It also examines the materials used and whether alternatives exist or could be found.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Know the methods used to produce electrical energy
2. Understand the properties and applications of conductors, insulators and magnetic materials
3. Understand the physical arrangements of supply, transmission and distribution equipment
4. Understand how electrical energy is used to support applications of electrical technology.
Unit content

1 Know the methods used to produce electrical energy

*Electromagnetic generation*: characteristics and principles of operation of alternating current (AC) and direct current (DC) generators, e.g. relative motion between conductors and magnetic fields, production and regulation of AC using field/slip-ring control, production of DC using commutators and brushgear; features of different types of electrical power generating stations and their energy sources, e.g. coal, gas, oil, nuclear, hydroelectric, pumped storage, wind farms, tidal, biomass

*Solar panels*: developments in photovoltaic cells, e.g. photo-electric effect, PN-junction for basic photovoltaic, need for use of converters to convert to alternating current source; small and large scale applications of solar panels, e.g. roadside furniture such as school crossing warning signs, domestic/commercial roofing

*Electro-chemical cells and batteries*: construction, applications and disposal; primary and secondary, e.g. lead/acid, alkaline, nickel-iron (NiFe), nickel-metal-hydride (NiMH), nickel-cadmium (NiCad), lithium

2 Understand the properties and applications of conductors, insulators and magnetic materials

*Conductors*: properties, e.g. conductivity, resistivity, tensile strength, rigidity; electrical applications of solid conducting materials, e.g. copper, aluminium, steel, brass, carbon, soil (for Earth continuity); applications of liquids and gases e.g. electrolytes, fluorescent and discharge lighting

*Insulators*: properties, e.g. resistivity, maximum voltage capability, operating temperatures, mechanical strength; applications of solid, liquid and gas insulating materials, e.g. polyvinyl chloride (PVC), butyl rubber, glass, paper, oil, air

*Magnetic materials*: properties, e.g. retentivity, coercivity, B-H curve, hysteresis, iron losses; electromagnetic applications, e.g. permanent magnets, electromagnets, soft iron, silicon steel, mu-metal, ferrites for use at audio and high frequencies

3 Understand the physical arrangements of supply, transmission and distribution equipment

*Electrical generation*: energy conversion methods, e.g. generating plant and equipment (coal, gas, oil, nuclear, hydroelectric, pumped storage, wind farms, tidal, biomass, photo voltaic, Gas turbine ); by-products (useful and not so useful, CO₂ emissions, carbon neutral); speed governing and voltage regulation for supply standardisation

*Electrical transmission*: use of transformers for feeding into and out of the grid network; construction and operation of power transformers, e.g. double-wound and autotransformers; construction and operation of switchgear and protection systems, e.g. air circuit breakers, oil circuit breakers, fuses, over current and over voltage devices; transmission voltages, e.g. 400 kV, 275 kV and 132 kV and the reasons for using them; cross-channel/intercontinental links for electricity supply

*Electrical distribution*: ring and radial feeders; sub-stations; use of distribution voltages e.g. 33 kV, 11 kV; plant and equipment e.g. isolators, oil breakers, air breakers; three-phase and single-phase distribution systems and voltages (400V and 230V); earthing arrangements
4 Understand how electrical energy is used to support applications of electrical technology

*Applications of electrical technology:* manufacturing, e.g. automated processes, robotics, control systems; healthcare, e.g. magnetic resonance imaging (MRI) scanners, operating theatre uninterruptible power supplies (UPS); entertainment, e.g. sound and video systems, theme parks, music festivals; transport, e.g. electric trains, inner-city trams, electric cars, solar-powered space travel
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td>P1 describe the characteristics and principles of operation of a DC electromagnetic generator</td>
</tr>
<tr>
<td>P2 describe the characteristics and principles of operation of an AC electromagnetic generator</td>
</tr>
<tr>
<td>P3 describe the operation and an application of a solar power source</td>
</tr>
<tr>
<td>P4 describe the characteristic features of two different types of electro-chemical cells or batteries</td>
</tr>
<tr>
<td>P5 explain the properties and a typical application of a solid and a liquid or gas electrical conductor</td>
</tr>
<tr>
<td>P6 explain the properties and a typical application of a solid and a liquid or gas electrical insulator</td>
</tr>
<tr>
<td>P7 explain the properties and an application of two different magnetic materials commonly used in electrical and electronic engineering</td>
</tr>
</tbody>
</table>
## Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P8</strong> describe the arrangements and features of an electrical supply system from generation through to transmission and distribution to end users</td>
<td><strong>M2</strong> explain the reasons for the use of a range of voltages in an electricity supply system</td>
<td><strong>D2</strong> evaluate an electrical supply system suggesting possible improvements.</td>
</tr>
<tr>
<td><strong>P9</strong> explain two different applications of electrical technology and, for each of them, describe how electrical energy is used to enable them to function.</td>
<td><strong>M3</strong> explain how a practical application of electrical technology could be improved by making effective use of available technologies.</td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Although this unit could be delivered completely in class, the learning and assessment experience is much more relevant if the learners make use of the outside world and visit real applications of electrical technologies.

The pass criteria could be achieved through the use of written assignments and/or illustrated posters with relevant text boxes to describe the concepts covered, for example the characteristics and principles of operation of a DC electromagnetic generator.

For P1 (DC generator) and P2 (AC generator), motor vehicle/motorcycle parts are cheap and are a relatively safe resource that could be investigated and described. The larger items in power stations are just scaled-up models (figuratively speaking) with somewhat larger brush gear and coils, etc. Hence, an assignment could require learners to use such an easily obtainable device to help them describe the principles and operation of electromagnetic generation.

Learners could then use this simple model to illustrate the similarities and differences between these and larger machines when they consider the characteristics of a power station and its energy sources (for example a coal, gas, oil, nuclear, hydro-electric, pumped storage, wind farm, tidal, biomass) used to generate power commercially.

Solar cells (P3) can be found on a range of items, including calculators and street signs, as well as small kits used by many college and school science departments. Learners’ description of their operation should be limited to developments in photovoltaic cells and a consideration of the action of the atoms in crystal lattice PN-junctions when subjected to illumination. An in-depth atomic theory explanation is not expected.

Cells and batteries take many forms and, although a wide range should be taught, learners only need to select two for P4. Liquid conductors and insulators (P5 and P6) could also be part of learners’ response to P4 if a wet cell such as lead acid were to be described. Reference could also be made to the potential hazard of topping up the cell with tap water if living in a hard water, high mineral content region. This would short out the plates and ruin the cell(s), whereas distilled or de-ionised water would not.

There is a wide range of other examples that could be examined for P5 and P6. For example, oil is a good insulator and is used on oil circuit breakers to quench the spark and prevent conduction. Fluorescent lights contain a variety of conductive gases and vapours requiring different arcing voltages and producing a range of colours. Overhead lines are insulated by air and any simple electric switch uses air as an insulator when in the ‘off’ position.

To cover P7, learners could consider electrical relays, motors, generators or similar devices that rely on electromagnetism. For example the soft iron formers of transformers and motors or a radio tuner’s use of ferrite core inductors. Some devices use permanent magnets, which could also be explained to address P7.

P8 requires learners to describe the arrangements and features of an electrical supply system to cover the key aspects of the content. This will include the generation method, transformer construction, types and operation, including single wound (autotransformers) and double wound voltages and distribution method. Learners might also include the finer details of distribution such as an electronics workshop having isolating transformers on bench supplies and reasons why they are used.
P9 provides an opportunity for learners to apply their knowledge by considering complete real-world applications. Examples could include lighting systems, sound systems or systems including motion (ranging from a model containing an electric motor to the electrification of the rail network). The Docklands Light Railway (DLR) and some airport transport systems have no driver and an investigation of these systems could allow learners to work on an area in which they may be interested and learn through the application of electrical technology. This should take learners into such aspects as electromagnetic effects and sensors for control, computer control, or the requirement for emergency or uninterrupted power supplies (UPS).

To achieve a merit, learners should differentiate between the mechanical prime movers of electromagnetic generators (M1), ranging from nuclear, coal and gas to wind and wave power and water storage such as that used at Dinorwic in Wales. Things to compare and contrast could include cost, response time, maximum demand, pollution, environmental issues, including appearance, hazards (and perceived hazards), locality of employees, life span of the project and post-service decommissioning.

While reporting on a supply system (P8), learners could address M2 by explaining why a range of voltages is used such as 15 to 25 kV at the generators and up to 400 kV for transmission, and the reasons for other voltages (for example 33 kV, 11 kV and 3.3 kV down to 400/230 volts) for light industrial and domestic end users.

To address D1, learners need to produce a thorough justification of why a nation might use a range of different energy sources. This could include (as a source and focus for the learner’s own justifications) suitably referenced third-party comments from parliamentary reports, Greenpeace opinions, local opposition groups and the projected impacts on national and global economies. Other considerations could include the future of different methods and fuels, lifespan of equipment and the actual fuel, cost of fuel production, hazards and environmental impact assessments.

D2 provides an opportunity for learners to develop the ideas of P8 and M2, electrical supply systems. For D2, learners are expected to provide suggestions for improvements to many aspects of effectiveness and efficiency of a chosen system. The suggestions made, and their explanations and justifications, should be feasible and possible. This could include an evaluation of learners’ ideas by a third party/engineer in that chosen industry. Learners could then make effective use of this through further reflection and subsequent development of their own work by following the professional feedback.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, P4, M1, D1</td>
<td>Electrical Energy Production</td>
<td>Learners produce an information poster for learners detailing the main forms of electrical energy production.</td>
<td>A written assignment with a series of tasks requiring learners to describe AC and DC generators, solar power and two different batteries.</td>
</tr>
<tr>
<td>P5, P6, P7</td>
<td>Conductors, Insulators and Magnetic Materials</td>
<td>Learners need to produce a report detailing the properties and applications of different conductors, insulators and magnetic materials to determine the best for a particular application.</td>
<td>A written assignment with a series of tasks requiring learners to explain conductors, insulators and magnetic materials.</td>
</tr>
<tr>
<td>P8, M2, D2</td>
<td>Electrical Supply, Transmission and Distribution Equipment</td>
<td>Learners produce a report on the electrical supply system.</td>
<td>A written assignment for which learners describe the electrical supply system and explain the reasons for a range of voltages.</td>
</tr>
<tr>
<td>P9, M3</td>
<td>Applications of Electrical Technology</td>
<td>Learners have been asked to investigate the use of electrical energy.</td>
<td>A written assignment requiring learners to explain the use of electrical energy in different applications.</td>
</tr>
</tbody>
</table>
Essential resources

Centres will need simple models or alternators/dynamos from motor vehicles to demonstrate AC and DC generation. Because cells and batteries can be hazardous, videos/DVDs or pictures are recommended to illustrate these along with manufacturers’ data.

Indicative reading for learners

Textbooks


Unit 38: Electrical Installation

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

We all use electricity, almost without thinking about it. Although we are surrounded by and rely on electrical appliances, most people have little understanding of how electricity arrives at its final point of use.

This unit will give learners an understanding of the circuits regularly found in domestic premises, the components and accessories used, cables, sockets and light switches etc. Learners will gain some practical experience of constructing and investigating some of these circuits and systems. The unit will provide an understanding of installations where there is an increased shock risk, mainly to illustrate the hazards associated with these areas.

Safety and safe working practices are essential to reduce the risks of working with electricity to an absolute minimum. Learners will gain a knowledge of selecting types of cable for their insulation properties, current-carrying capacity and physical strength, and choosing the correct type and rating of protective devices to prevent over-current. Learners will also be introduced to how the design and provision of earth-bonding conductors helps prevent electric shock.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Be able to interpret lighting and power circuits diagrams
2. Understand the methods used to protect circuits
3. Be able to install and test lighting and power circuits
4. Know the statutory and non-statutory regulations relating to the provision of an electrical installation.
Unit content

1 Be able to interpret lighting and power circuits diagrams

Lighting circuits: e.g. one way, two way (loop-in method, junction box, singles)

Power circuits: e.g. fused plug socket outlet, ring circuit, radial circuit, switched fused spur, cooker, immersion heater, heating control

Choice of cables and protection devices: cable calculations, e.g. design current, correction factors, tabulated cable ratings and voltage drops; maximum demand and diversity, e.g. determination and application of maximum demand and diversity (individual householder, small shops/offices, small hotels/guest houses); segregation of circuits; categories of circuit proximity to non-electrical services

Increased risk of electrical shock areas: e.g. inside the main property (rooms containing a fixed bath or shower, sauna, swimming pool), equipment outside equipotential zone (shed, garage, workshop, garden, pond)

2 Understand the methods used to protect circuits

Types of over-current protection device: fuse, e.g. rewireable, cartridge; miniature circuit breakers (MCBs); residual current breaker with overload protection (RCBO)

Circuit protection methods: earthing and bonding, e.g. ADS automatic disconnection of supply, earthed neutral system, system classification (terra-terra (TT) and terra-neutral (TN) with combined (C) and separate (S) variations (TNC, TNS, TNC-S)), earth electrodes, protective multiple earthing (PME), earthing terminal; residual current devices (RCDs); other protection methods, e.g. class 2 equipment, class 3 equipment; cable size e.g. from tables for current loading and thermal constraints; protection from mechanical damage, e.g. armoured cable, cable trunking, cable tracking

3 Be able to install and test lighting and power circuits

Lighting and power circuits installations: use of flexible and non-flexible cable; use of tables to select cable type and size; circuit components (consumer unit/circuit isolation device, light switching, e.g. 1-gang, 2-gang, 1-way, 2-way, intermediate; power socket outlets, e.g. ring, radial, switched fused spur connection units; other types of power circuits, e.g. immersion heater, heated towel rail)

Circuit testing: for compliance with circuit diagram, e.g. operation of switches, circuit continuity, polarity, insulation resistance checks

4 Know the statutory and non-statutory regulations relating to the provision of an electrical installation


Non-statutory regulations: scope, object, principles and use of relevant sections of the wiring regulations, e.g. BS 7671: 2008 plus amendments and relevant guidance notes
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<p>| Assessment and grading criteria | To achieve a pass grade the evidence must show that the learner is able to: | To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to: | To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to: |
|---------------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <strong>P1</strong> interpret two different lighting circuit diagrams, explaining the function of the circuits and why the cables and protective devices have been chosen for each installation | <strong>M1</strong> carry out calculations to obtain cable sizes, given the power and voltage, taking installation methods and correction factors into account | <strong>D1</strong> analyse the design specification of a domestic installation with at least six circuits, including the use of diversity when determining the final maximum demand current |
| <strong>P2</strong> interpret two different power circuit diagrams, explaining the function of the circuits and why the cables and protective devices have been chosen | | |
| <strong>P3</strong> describe the extra considerations required for an electrical installation in an area of increased risk of electrical shock | <strong>M2</strong> explain the steps taken to prevent electric shock by indirect contact | |
| <strong>P4</strong> explain the operation of the three types of over-current protective devices, describing a suitable electrical installation application for each | | |
| <strong>P5</strong> describe the function and application of two different circuit protection methods | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>To achieve a pass grade the evidence must show that the learner is able to:</strong></td>
</tr>
<tr>
<td><strong>P6</strong> install and test two different lighting circuits in accordance with current wiring regulations</td>
</tr>
<tr>
<td><strong>P7</strong> install and test two different power circuits in accordance with current wiring regulations</td>
</tr>
<tr>
<td><strong>P8</strong> describe the statutory and non-statutory regulations that apply to an electrical installation on the inside of a building</td>
</tr>
<tr>
<td><strong>P9</strong> describe the statutory and non-statutory regulations that apply to an electrical installation on the outside of a building.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

P1 requires learners to demonstrate their ability to interpret two different lighting circuit diagrams, explain the function of each circuit and say why the cables and protective devices have been chosen for each of the installations.

P2 is similar but focuses on power circuit diagrams. In order to satisfy the cable calculation requirements of P1 and P2, learners should perform calculations based on design current. However, to satisfy M1, learners should take into account appropriate correction factors, use tabulated cable ratings and work with voltage drops.

For P3, learners could use diagrams/sketches to help describe a relevant installation inside a property or equipment outside the equipotential zone. This should include the positioning of equipment and any other safety features and reference to appropriate regulations.

For P4, learners must explain the operation of all three types of overcurrent protective device listed in the unit content (fuse, miniature circuit breaker, residual current breaker with overload protection). They will then need to describe a suitable electrical installation application for each device.

For P5, learners need to describe the function and application of two different circuit protection methods (for example earthing residual current devices) or any other protection methods (for example class 2 equipment, class 3 equipment). Learners must refer to issues of cable size (for example from tables for current loading and thermal constraints) and the method used to protect the circuit from mechanical damage (for example armoured cable, cable trunking, cable tracking).

P6 and P7 require learners to install and test two different lighting circuits and two different power circuits in accordance with current wiring regulations. One approach to assessment might be to use these four circuits as the focus for the assessment of all the other criteria. This type of approach to assessment would provide maximum coherence but, by necessity, would fragment the criteria. Therefore centres would need to take care when tracking learner achievement.

Records for each installation would need to be planned carefully to indicate learners have met the relevant criteria and unit content, and only when all four installations have been completed satisfactorily would each criterion be fully achieved.

Evidence for this work could be a mix of tutor observation records, annotated photographic evidence, learners’ research and preparation notes, and formal reporting. For example, in addition to the installation, a formal written description of the extra considerations required for an electrical installation in an area of increased risk of electrical shock would be required. The evidence could be brought together as a portfolio record for each installation. The constraint to this approach would of course be the centre’s ability to provide sufficient installation facilities to cope with a reasonable group size.

For P8 and P9, descriptions of the statutory and non-statutory regulations that apply to an electrical installation on the inside and outside of a building could also be planned to fit into the above assessment approach. Learners will need to summarise the relevant legislation (statutory and non-statutory) that needs to be considered when electrical installation work is carried out in and around buildings. The list given in the unit content should not be seen as exhaustive and centres should ensure that the most current, relevant and up-to-date legislation is covered.
Less integrated approaches could also be used to good effect where equipment or other constraints apply. However, a circuit should only be deemed to be correctly wired when any single cores of conductors with diameters less than 2.5 mm² are terminated into a screwed terminal. Other elements of good practice also need to be demonstrated, all connections must abide by the latest UK/EU colour code standards (or equivalent for other countries), and the circuit must work.

M1 and D1 build on learners’ understanding from P1 and P2. For the application of diversity in D1, the circuits could include examples such as upstairs and downstairs ring circuits, upstairs and downstairs lighting circuits, cooker (with or without 13 A socket), immersion heater, or outside supply to a garage/shed.

Having carried out the installations for P6 and P7, learners should be expected, as simply a matter of good practice, to check their own work for compliance ahead of assessment. This can be extended to meet M3, where learners inspect others’ work.

In doing this, learners should follow relevant inspection and test procedures using appropriately annotated inspection and testing documentation (such as those illustrated in the wiring regulations or the on-site guide or other centre devised certification). The activity for this could be the supervised assessment of the work carried out by a fellow learner who is presenting their installation as evidence for P6 and P7.

M2 builds on the work carried out for P3, P4 and P5. This will include earthing connections and other means. To differentiate the work at merit from that at pass, it is expected that at this level learners not only know what needs to be done but can explain and justify the actions taken. This should include, why an RCD is needed outside the equipotential zone, and how it operates, why it needs to operate in a certain specified time and the relevance of its current sensitivity to the effects of electricity passing through a human body or livestock.

D2 builds on the inspection work undertaken for M3. Learners are required to explain and justify the inspection and testing methods carried out for one lighting and one power circuit. This should take into account the what, where and how of the inspection process for compliance with circuit diagram, for example operation of switches, circuit continuity, polarity, insulation resistance checks and should give learners an opportunity to demonstrate their understanding of the unit as a whole.

The evidence, which is likely to be a technical report, should clearly explain what learners were doing during the inspection and why. It should also include what they were looking for and why; which test equipment they used, how and why it was ‘proved’ before and after use and, finally, how well the results show the installations comply with the respective circuit diagrams.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, D1</td>
<td>Interpreting Wiring Circuit Diagrams</td>
<td>Learners interpret given lighting and power circuit diagrams, perform calculations of cable size and analyse the given design specification of a domestic electrical installation.</td>
<td>A report, including supporting calculations, engineering sketches and diagrams, and design analysis</td>
</tr>
<tr>
<td>P3, P4, P5, M2</td>
<td>Investigating Circuit Protection and Safety Techniques</td>
<td>Learners investigate, inspect and report on different measures for providing protection against circuit overload and the risk of electrical shock.</td>
<td>A report, including descriptions and explanations supported by engineering sketches and diagrams.</td>
</tr>
<tr>
<td>P6, P7, M3, D2</td>
<td>Implementing Electrical Installations</td>
<td>A practical activity in which learners install, test and inspect prescribed lighting and power circuits.</td>
<td>A report, including descriptions and evaluations supported by engineering sketches and diagrams.</td>
</tr>
<tr>
<td>P8, P9</td>
<td>Non-statutory and Statutory Wiring Regulations</td>
<td>Learners investigate and then describe pertinent wiring regulatory requirements.</td>
<td>A report, including descriptions supported by engineering sketches and diagrams.</td>
</tr>
</tbody>
</table>
**Essential resources**

Centres will need to provide access to suitably equipped workshops for the installation of electrical circuits (preferably with some installation onto walls or, where necessary boards), together with relevant test equipment to carry out tests to prescribed regulations (for example BS7671 and Guidance Note 3).

Learners will also require access to a range of wiring diagrams, test rigs and wiring boards, electrical tools and components and cabling required for lighting and power installations.

Centres will need to provide appropriate documentation such as statutory and non-statutory regulations, manufacturers’ catalogues, data sheets and relevant cable, component and equipment specifications.

**Indicative reading for learners**

**Textbooks**


Unit 39: Electronic Measurement and Testing

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Practical electronic engineering demands the extensive use of electronic test equipment and measurement techniques. These range from basic measurements of parameters such as voltage, current and resistance, to highly sophisticated software-controlled measurements based on advanced mathematical techniques such as Fast Fourier Transformation (FFT).

This unit will give learners an understanding of a variety of electronic measurement equipment such as voltmeters, ammeters, analogue/digital multimeters and oscilloscopes or specialist diagnostic equipment. The unit also examines a range of electronic test equipment such as signal generators, digital counter/frequency meter, alternating current (AC) bridge, logic probe, logic pulsar and current tracer.

Learners will develop an understanding of the function, features and characteristics of electronic measurement and test equipment. They will also gain practical experience of their use when carrying out electronic testing and measurements in a wide range of electronic engineering applications. This will include selecting, connecting and operating different types of test equipment and applying measurement techniques.

Learners will demonstrate that they can apply common testing methods and assess errors inherent in the instruments used. Particular attention is paid to ensure that the test procedure, as well as the test and measurement equipment used is fit-for-purpose and properly calibrated. Learners will be expected to explain the effects of instrument characteristics such as accuracy, display resolution and loading and how these affect the measured quantity.

Finally, learners will be introduced to the use of virtual test instruments and software to make measurements and analyse measurement data. They will examine equipment such as a digital storage oscilloscope, spectrum analyser, digital voltmeter, digital frequency meter, arbitrary waveform generator or logic analyser. Learners will be expected to make measurements using virtual instruments and analyse the captured data using appropriate software.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand the function, features and characteristics of electronic measurement and test equipment
2. Be able to select and use electronic measurement and test equipment to make meaningful measurements on an electronic circuit
3. Know the principles of calibration and configuration of electronic test equipment
4. Be able to select and use virtual test instruments and software to make measurements and analyse measurement data.
Unit content

1 Understand the function, features and characteristics of electronic measurement and test equipment

Function of equipment: as appropriate to the measurement and test equipment, e.g. accurate measurement of alternating current (AC) and direct current (DC) voltage and current, resistance, waveform and distortion measurement, accurate measurement of waveform parameters (period, duty cycle, on-time, off-time, rise time, fall time, frequency, pulse repetition frequency (PRF), impedance, logic level)

Features of equipment: as appropriate to the measurement and test equipment, e.g. displays and display technology, input and output connectors, attenuators, manual and automatic range selection (auto ranging), in-built calibration facilities, portability, power sources, external bus interfaces

Characteristics of equipment: measurement and test equipment specifications, e.g. input impedance, output impedance, resolution, accuracy, distortion, bandwidth, input signal range, output level, sample rate, trigger sources

Measurement instruments: meters (voltmeter, ammeter); analogue/digital multimeter; oscilloscope, to include specialist or manufacturer diagnostic/measuring equipment

Electronic test equipment: signal generator, e.g. audio frequency (AF), radio frequency (RF) and pulse generators, waveform/function generators; digital counter/frequency meter; AC bridge; logic probe; logic pulsar; current tracer

2 Be able to select and use electronic measurement and test equipment to make meaningful measurements on an electronic circuit

Selection of equipment: selection based on instrument specifications, characteristics and limitations, e.g. output, level, input sensitivity, frequency range, accuracy, resolution and distortion

Measurement techniques: test-point voltage and waveform measurement; supply voltage and current measurement; power, impedance and phase angle measurement using variable loads; frequency and PRF measurement; rise and fall time measurement; distortion and noise measurement (qualitative only); use of test specifications, e.g. in the case of a variable DC power supply, measurement of the actual output voltage delivered at a specified load current when the power supply has been set to a specified voltage under no-load conditions; in the case of an audio amplifier, measurement of the output power delivered to an externally connected load of specified resistance, using a specified test frequency and waveform and at a specified level of distortion

Measurements: use of test points, test leads and probes; minimisation of loading effects; use of appropriate instrument ranges; precautions to be taken when measuring high voltages and currents; precautions to be taken when working on low voltage and computerised systems; effect of DC levels on AC signals and waveforms; effect of signals present at DC test points; effect of drift and temperature; need for calibration; relevant test specification and measurement techniques, e.g. sampling, averaging

Electronic equipment: industrial/consumer electrical and electronic equipment, including low-voltage DC power supplies, e.g. linear, switched-mode types; amplifiers, e.g. AF, RF, small-signal, power; oscillators, e.g. sinusoidal, square wave, crystal controlled; radio equipment, e.g. radio receivers, low-power transmitters and transceivers; digital electronic equipment, e.g. microcontrollers, microcomputers, programmable logic controllers;
manufacturer specific equipment; video equipment, e.g. television and video players/recorders

3 Know the principles of calibration and configuration of electronic test equipment

Calibration principles: procedures, e.g. check, adjust, systematically standardise measuring instrument, set-up arrangement; reference standards, e.g. standard resistors, standard inductor; theory, e.g. accuracy, uncertainty; impact of calibration on quality, productivity and safety; applications, e.g. during manufacture, following installation, periodic scheduled maintenance, in response to identified deviation, after repair or change in environment; terminology, e.g. zero shift, range (or span) error, combined zero shift and range error, non-linearity

Health and safety issues: e.g. precautions to be observed when setting and adjusting mains supply voltages, replacing/charging/disposing of batteries, dismantling and reassembling equipment, removal/replacement of external and internal covers, making adjustments on ‘live’ equipment, continuity of earth (grounding or bonding) of electrical equipment, safety cut-outs and residual current device (RCD), earth leakage circuit breaker (ELCB)

Configuration issues: pre-conditions and checks to ensure that system/equipment is safe to test and instruments safe to use; test equipment set-up, e.g. use of the equipment manufacturer’s procedures, using commissioning guides

4 Be able to select and use virtual test instruments and software to make measurements and analyse measurement data

Virtual measurement and test system: e.g. digital storage oscilloscope, spectrum analyser, digital voltmeter, digital frequency meter, arbitrary waveform generator, logic analyser

Measurement techniques, connection, hardware and software: tests carried out on electronic equipment using virtual test and measuring instruments; instrument connection, e.g. external/internal PC interface, instrument connection standards (parallel port, serial port, USB, PCI/PXI bus, IEEE-488, PCMCIA); use of hardware and software to carry out measurements, e.g. voltage, frequency, frequency spectra measurements (for sinusoidal and non-sinusoidal waveforms); measurement software, data storage and data transfer, e.g. to a spreadsheet, automated measurement/data collection techniques
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong> explain the function, features and characteristics of a measurement instrument</td>
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<tr>
<td><strong>P2</strong> explain the function, features and characteristics of three different pieces of electronic test equipment</td>
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</tr>
<tr>
<td><strong>P3</strong> select and use test equipment and measuring techniques to take measurements from three different pieces of electronic equipment</td>
<td><strong>M1</strong> use a manufacturer’s recommended procedure, together with laboratory instruments and standards, to calibrate and configure an item of electronic test equipment</td>
<td><strong>D1</strong> evaluate the accuracy of own test measurements and relate them to limitations of the test equipment, test procedures, or possible emerging fault conditions</td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> explain the importance of test specifications as an aid to ensuring the validity and consistency of measurements</td>
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<tbody>
<tr>
<td><strong>P5</strong> describe the principles and need for the calibration of an item of electronic test equipment</td>
<td><strong>M2</strong> explain the importance of resolution, accuracy, sensitivity bandwidth and input impedance on the performance of a piece of test equipment</td>
<td><strong>D2</strong> devise and demonstrate a calibration procedure for an item of electronic test equipment.</td>
</tr>
<tr>
<td><strong>P6</strong> explain the health, safety and configuration issues that need to be considered when connecting test equipment to an item of electronic equipment that requires testing</td>
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<td></td>
</tr>
<tr>
<td><strong>P7</strong> use a virtual measurement and test system to carry out a test on a piece of electronic equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> describe the measurement techniques, instrument connection, hardware and software used.</td>
<td><strong>M3</strong> use appropriate software to display and analyse voltage/time data captured from a virtual oscilloscope.</td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

To achieve P1 and P2, learners will need to describe the function, features and characteristics of one measurement instrument and three different pieces of electronic test equipment. The evidence for this could be block diagrams/sketches (with appropriate annotation) and short notes. The actual function, features and characteristics explained will be dependent on the electronic test equipment selected, but examples of the types of things to consider are given in the unit content.

P3 requires learners to select and use test equipment and measuring techniques to take measurements from three different pieces of electronic equipment. These can be low-voltage DC power supplies, amplifiers, oscillators, radio equipment, digital electronic test, measurement or diagnostic equipment or display equipment. Further examples of each of these are provided in the unit content.

Learners will need to perform practical measurements in an electronic laboratory or electronic workshop. Given a particular measurement requirement (for example to investigate the frequency range of an oscillator), learners should then select the appropriate items of test and measurement equipment to carry out the task. Both the selected item(s) of test equipment and the measuring technique(s) should be appropriate to each measured quantity. For example, an oscilloscope and ×10 probe would not be appropriate for the accurate measurement of the output frequency produced by an oscillator. The three different pieces of electronic equipment should enable as wide a range of test equipment and measuring techniques to be applied as possible. All three pieces could come from one category (for example consumer electrical and electronic equipment) as long as the chosen equipment enables the use of a sufficient range of test equipment and measuring techniques. It is expected that all the content listed under measurement techniques and measurements will have been covered by the time learners have carried out the measurements on all three pieces of equipment.

Evidence for P3 is likely to take the form of tutor observations and learners’ records of the selection and use of equipment and techniques employed. Suitably annotated photographic records could also be used (for example a photograph of the equipment being tested, the test equipment and the test set-up, all suitably labelled to highlight the key features of the test/measurements).

For P4, learners should provide a written or verbal presentation to explain the importance of test specifications as an aid to ensuring the validity and consistency of measurement. Centres should ensure that learners have access to a variety of test specifications for common measurements (for example determining the output impedance of a power supply by voltage/current measurement when a suitably rated variable load is applied). The achievement of this criterion could be effectively linked with the practical work in any one of the tests carried out for P3.

P5 requires learners to describe the principles and need for calibration of an item of electronic test equipment. Again, one of the tests undertaken for P3 could provide the focus for this criterion. The description, which is likely to be a written report, must include the electronic test equipment calibration procedures that need to be carried out, the reference standards required and any relevant theory. Examples of each of these and typical applications are given in the unit content. As an aid to understanding the calibration process, centres should demonstrate the calibration procedures for equipment used in the laboratory (for example oscilloscopes, digital multimeters, signal generators, etc.).
For P6, learners must describe the health, safety and configuration issues that need to be considered when connecting test equipment to an item of electronic equipment that requires testing. The health and safety issues considered will depend on the equipment being tested. The configuration issues considered must, as a minimum, enable learners to take into account the required pre-conditions and checks to ensure that it is safe to test the system/equipment. For example, the selection of an adequately rated load in terms of both impedance and power rating when testing an audio amplifier or the need to check that an oscilloscope probe is correctly matched to the oscilloscope that it is to be used with. Learners will also need to ensure instruments are safe to use (for example use of a high-voltage probe when measuring DC voltages in excess of 500 V) and test equipment set-up correctly, for example use of equipment manufacturer’s procedures, using commissioning guides. Again it would make sense to link this criterion to one of the tests undertaken for P3.

To satisfy P7 and P8, learners should use a virtual measurement and test system to carry out a test on a piece of electronic equipment. They should provide a written or verbal description of the procedure used, explaining the connections made, the software settings, and the measuring techniques used. A typical example would be the use of a virtual digital storage oscilloscope used in conjunction with a personal computer (PC). Learners should connect and configure the instrument in conjunction with the software running on the PC and select, for example, appropriate sampling rates, input ranges and display and data capture settings. Evidence of individual learner’s work can most conveniently be presented in the form of a selection of screen dumps that have been suitably annotated by the learner.

For M1, learners are required to calibrate and configure a test instrument (such as a waveform generator), using the manufacturer’s recommended procedures and appropriate laboratory instruments and standards. Learners should be supplied with relevant documentation (for example manufacturer’s handbook) and laboratory standards (such as a standard frequency or time generator). Evidence is likely to be a logbook record of the calibration exercise or a technical report of the calibration activity. Tutor observation records should be used to support either of these forms of evidence. There is a clear link between this merit criterion and P5.

To achieve M2, learners need to explain the importance of resolution, accuracy, sensitivity bandwidth and input impedance on the performance of a piece of test equipment. This could be achieved as a natural extension to one of the tasks carried out for P3.

To satisfy M3, learners should use a virtual storage oscilloscope (using a PC with appropriate interface hardware and software) to display and analyse a waveform. Note that the emphasis should be on the analysis of the waveform rather than its display. A typical example might involve the production of a frequency spectrum for the sampled waveform using FFT techniques. Once again, learners should keep a record of their work in a logbook, supported by tutor observation records. Relevant screen dumps and print outs that have been suitably annotated by the learner could also be incorporated.

Learners’ work towards D1 should require them to evaluate the accuracy of their own test measurements and relate them to limitations of the test equipment, test procedures, or possible emerging fault conditions. For example, learners should be aware of the inability of an oscilloscope to accurately display a transient pulse due to the oscilloscope’s own finite rise-time and bandwidth. Another example would be the need to be aware of the effects of aliasing on the captured and displayed waveform when sampling a fast waveform.
For D2, learners need to devise and demonstrate a calibration procedure for an item of electronic test equipment. A typical example might be a procedure to calibrate a $\times10$ oscilloscope probe using a fast-rise time square wave generator, a high-speed oscilloscope, and a matching $\times10$ probe. Evidence is likely to be in the form of a technical report although it would be beneficial if the devised calibration could be linked into the work done for P5 and M2.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2</td>
<td>Measurement Instruments and Test Equipment</td>
<td>Learners are requested to generate an information booklet and an accompanying report for new staff.</td>
<td>A written assignment.</td>
</tr>
<tr>
<td>P3, P4, P5, P6, M1, M2, D1, D2</td>
<td>Selecting, Using and Calibrating Electronic Test Equipment</td>
<td>Learners have been asked to show a new learner how to take measurements from electronic equipment and talk them through the calibration of test equipment and relevant health, safety and configuration issues.</td>
<td>A practical assignment with additional written tasks.</td>
</tr>
<tr>
<td>P7, P8, M3</td>
<td>Virtual Testing</td>
<td>Learners have been asked by their employer to carry out tests on a piece of electronic equipment.</td>
<td>A practical assignment.</td>
</tr>
</tbody>
</table>
Essential resources

Centres will need to provide access to an electronics laboratory fitted with a range of electronic test and measurement equipment (such as multimeters, signal generators, oscilloscopes, or specialist manufacturer equipment within industry etc.). A limited number of specialist items of electronic test equipment and calibration sources (for example standard cells and off-air signal sources) should also be available. Specialist items of electronic equipment (such as AC bridges, earth continuity testers, logic analysers, component testers etc.) may be required as appropriate to the needs of local industry.

A small number of computer-based virtual instruments should also be available together with the appropriate hardware and software (for example LabVIEW, DASYLab, DADISP, MATLAB etc.). Test and measurement applications should be installed on these systems.

Indicative reading for learners

Textbooks

Hughes E – Electrical and Electronic Technology (Pearson Education, 2012)
ISBN 9780273755104

ISBN 9780750669238

Tooley M – PC Based Instrumentation and Control (Routledge, 2005)
ISBN 9780750647168
Unit 40: Features and Applications of Electrical Machines

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

All electrical machines use applications of electro-magnetic principles where electric currents create magnetic fields, which either attract or repel each other. This is the basis of all electric motors, whether they operate on alternating current (AC), direct current (DC) or are universal motors that operate on both.

Transformers are devices that also use the principle of electromagnetism. These are generally very efficient and their output power can be almost 100 per cent of the input power, depending on the application.

This unit has been designed to help learners understand the complexities of electromagnetism and its applications to everyday electrical devices, systems and apparatus. Learners will consider a range of machines, their application and their control. In addition, the unit will help learners understand relevant electrical hazards, legislation, regulation and standards.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Know the electrical hazards and the legislation, regulations and standards related to working with electrical apparatus
2. Understand features and applications of alternating current (AC) machines
3. Understand features and applications of direct current (DC) machines
4. Know how electrical machine control circuits and systems operate.
Unit content

1  Know the electrical hazards and the legislation, regulations and standards related to working with electrical apparatus

*Electrical hazards:* safe working procedures, e.g. isolation (safe isolation, switch off, lock off, display notices, testing for dead with test lamp and proving unit), earthing, interlocking, warning notices, permit to work; risk assessment when working on electrical apparatus, e.g. hazard evaluation and recording of risk, controlling risk; personal protective equipment (PPE), e.g. insulated gloves, mats, tools, barriers

*Legislation, regulations and standards:* e.g. Health and Safety at Work etc. Act 1974, Electricity at Work Regulations 1989, Personal Protective Equipment at Work Regulations 1992, Electrical Equipment (Safety) Regulations 1994, Machinery Directives, Health and Safety Executive (HSE) publications, e.g. GS38, Codes of Practice, British and International Standards, BS 7671 17th Edition IEE Wiring Regulations

2  Understand features and applications of alternating current (AC) machines

*Alternating current (AC) motors:* single and polyphase; construction, principles of operation, starting characteristics and torque; types (induction motors, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives); applications of AC motors, e.g. conveyor belt drives, pumps, machine shop equipment, fixed loads, variable loads

*AC generator:* types, e.g. single-phase, polyphase; construction and principles of operation; applications, e.g. stand-by generators, remote site generators, vehicle alternators with regulation and rectification

*Transformers:* principles of operation; efficiency and losses; construction of single and double wound; types, e.g. step up, step down, safety isolating transformer; applications, e.g. incoming mains step down, portable transformer for hand tools, safety isolating transformer for electrical test-bench work, machine power supplies

3  Understand features and applications of direct current (DC) machines

*Direct current (DC) motors:* types, e.g. series, shunt, compound (long and short shunt), brushless; construction, principles of operation, starting characteristics and torque; applications, e.g. motor vehicle starters and window operation, toys and models, industrial drives, crane hoists, fixed loads, variable loads

*DC generators:* construction and principles of operation; production and control of DC voltages and current; applications, e.g. motor vehicles, speed control/feedback systems (tacho-generators)
4 Know how electrical machine control circuits and systems operate

Stop/start/retain relay control: relay/contactor with retaining/latching contact; start, stop, overload, 'inch' (non-latching) control; remote stop/start; safety relays for production/manufacturing equipment, e.g. several guards closed sensors, oil level detectors, temperature sensors, body heat (passive infra-red) detectors; control circuits, e.g. AC machine control (direct on line (DOL), star-delta, soft start and other solid state techniques such as triac, inverter drives, slip ring rotor resistance control, auto transformer, power factor correction), DC machine control (starting methods and speed control such as face plate, solid state systems); emergency stop, e.g. closed contact device to stop the machine/system from running or starting and turn power off under emergency conditions; emergency stopping, e.g. dynamic braking by either DC injection braking or timed phase reversal, solenoid operated mechanical brakes, instantly stopping the machine
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tbody>
<tr>
<td>P1</td>
<td>describe hazards that may exist when working with two different pieces of electrical apparatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>describe control measures that should be used to reduce the risk of harm to self and others when working with two different pieces of electrical apparatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>describe aspects of legislation, regulations and standards that relate to work being carried out on two different pieces of electrical apparatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>explain the features, characteristics and application of two different types of AC motor</td>
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<td></td>
</tr>
<tr>
<td>P5</td>
<td>explain the features, characteristics and an application of one type of AC generator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>explain the operational features of a speed control system for an AC machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>compare the applications of a DC and an AC motor for two contrasting modern electrical installations</td>
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### Assessment and grading criteria

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<td><strong>P6</strong> explain the features, characteristics and application of two different types of transformer</td>
<td></td>
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</tr>
<tr>
<td><strong>P7</strong> explain the features, characteristics and application of two different types of DC motor</td>
<td><strong>M2</strong> explain the operational features of a speed control system for a DC machine</td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> explain the features, characteristics and an application of a DC generator</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> describe the operation and use of a stop/start/retain relay control circuit for an AC or DC machine.</td>
<td><strong>M3</strong> explain the use of a safety relay system and how its use addresses the issues raised in relevant legislation, regulations and standards.</td>
<td><strong>D2</strong> compare the construction and operation of two different types of stop/start/retain relay control circuit for either an AC or a DC machine.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

P1, P2 and P3 are linked and are likely to be achieved through investigations based on the same two different items of electrical equipment, for example transformers, isolators, AC and DC motors. Evidence could be presented in the form of a written report or as a presentation to a group using appropriate visual aids.

When describing hazards and control measures for P1 and P2, learners should include all the aspects identified in the unit content.

For P3, learners should include relevant quotes from their sources and specific references, and it is important that these are shown to be specific to the work being undertaken and not just general quotes.

For P4, learners need to carry out investigations based on two different types of AC motor (for example induction, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives, single or polyphase motors). Ideally, these should be combined into one single investigation of two different motors rather than two separate investigations. This will avoid the need to assess the criterion twice before it can be reported as achieved. Learners need to describe the features, characteristics (for example construction, principles of operation, starting characteristics and torque) and a typical application for each type of AC motor considered. Evidence could include written descriptions plus relevant drawings, circuit diagrams, photographs and exploded views (as appropriate), annotated to aid the description.

P5 and P6 require a similar approach. However, it is important to note that while P5 only requires one AC generator to be considered, for P6, like P4 above, learners must describe two different types of transformer (for example step up, step down or safety isolating transformers).

P7 and P8 simply replicate the criteria for P4 and P5 but for two different DC motors (for example series, shunt, compound (long and short shunt), brushless) and one DC generator. As above, P7 should be done as one activity to avoid splitting the criterion.

P9 requires learners to describe the operation and use of a stop/start/retain relay control circuit. This can be an AC or DC machine and can be chosen by the tutor or the learner. The choice of AC or DC control circuit is only limited by the need to draw as extensively as possible from the unit content to cover such aspects as safety relays and emergency stop/stopping requirements. The assignment should be based on a practical investigation if possible and learners should provide a careful description of the circuit that they have investigated. This should include an itemised list of components (together with a description of the function of each component) and should be supported by a suitably annotated circuit diagram.

To achieve M1 and M2, learners should explain the operational features of the speed control systems for an AC machine and a DC machine respectively. Learners will need to consider the speed control aspects of machines in specific applications, which will draw from and build on their knowledge and understanding developed through P4–P8.

For M3, learners need to explain the use of a safety relay system and how the system addresses the issues raised in relevant legislation, regulations and standards. The system considered could be the same as that described for P9. Learners must set the circuit in a particular context or application and demonstrate that they understand the importance of the circuit in that application.
Learners must also have recognised the relationship of such a circuit to the requirements of relevant legislation, regulations and standards. Note that there is a further link from the work undertaken for P9 and M3 to that required for D2 (see notes below) and this might form the basis of a single assignment.

To satisfy D1, learners should show that they can bring together their understanding of P4–P8 by comparing the applications of a DC and an AC motor for two contrasting modern electrical installations. Learners should investigate two sufficiently complex and contrasting installations that enable them to draw from and show that they can apply the understanding that they have gained at pass and merit level. Typical applications might be a variable-speed motor drive for an electric vehicle and a high-torque constant-speed drive used in an industrial conveyor belt.

Learners should justify the type of DC and AC motor, as well as its supply configuration (for example triac speed controller) and output drive systems (for example gearbox or belt reduction system). They should also make reference to the operating principles and actual machine characteristics (for example starting torque, on-load torque, efficiency).

D2 builds on the work undertaken for P9 and M3. As such, the circuit considered for P9 could be one of the stop/start/retain relay control circuits that is used for comparison and against which a second is compared. However, centres may prefer to get learners to consider two completely different relay control circuits to provide them with a wider range of experience.
**Programme of suggested assignments**

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<tr>
<td>P1, P2, P3</td>
<td>Electrical Hazards and Legislation and Regulations</td>
<td>A technician has been asked to show potential electrical hazards to a new learner and explain the legislation and regulations with which they need to be familiar.</td>
<td>A written report or a presentation.</td>
</tr>
<tr>
<td>P4, P5, P6, P7, P8, M1, M2, D1</td>
<td>AC and DC Electrical Machines</td>
<td>A technician has been asked to write a report explaining and comparing the key features of a range of new AC and DC machines.</td>
<td>A written report.</td>
</tr>
<tr>
<td>P9, M3, D2</td>
<td>Machine Control Circuits and Systems</td>
<td>A technician has been asked to describe the operation of a stop/start/retain relay control to a new member of staff.</td>
<td>A written report.</td>
</tr>
</tbody>
</table>
Essential resources

Centres will need a workshop equipped with electrical machines and associated switchgear and control equipment. Learners will require access to a range of AC and DC motors and generators. A selection of different types of transformer (for example step-down, step-up, isolating variable voltage) will also be required. In addition, to permit testing of motor speed controllers, learners will require one or more variable speed controllers (for both AC and DC motors) together with variable loads and machine braking systems.

Learners will also require access to appropriate statutory and non-statutory regulations, health and safety legislation, as well as catalogues, data sheets and relevant equipment specifications.

Indicative reading for learners

Textbooks

Bird J – *Electrical and Electronic Principles and Technology* (Routledge, 2013) ISBN 9780415662857


Schultz G – *Transformers and Motors* (Newnes, 1997) ISBN 9780750699488
Unit 41: Three-phase Motors and Drives

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Three-phase motors are used where greater amounts of power are required and single-phase motors would not be effective. A good example of this is a large compressor where a constant speed is required. The two main advantages of three-phase types over single-phase types are the smoother torque they provide and a higher power to weight ratio, giving smaller frame sizes for comparable power outputs.

This unit will develop learners’ knowledge of the design and operation of three-phase motors that use electrical and electronic control devices to make them work. This will include being able to read and produce simple circuit diagrams and understand the principles of installation, commissioning and maintenance. Learners will be made aware of the requirements of a drive and the need for the motor and drive to be matched to the characteristics of the application.

The unit will provide a good foundation for anyone interested in taking up a career in the manufacturing or processing industry, particularly where large motor drives are involved.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Know how squirrel-cage and wound rotor three-phase induction motors operate
2. Know how three-phase synchronous and synchronous-induction motors operate
3. Understand the function and operation of motor starters and control gear
4. Understand a range of industrial applications for installing, commissioning and maintaining three-phase motors.
Unit content

1  Know how squirrel-cage and wound rotor three-phase induction motors operate

_Principle of operation_: production of rotating magnetic field, e.g. distributed winding, salient pole, frequency, pole pairs, synchronous speed, rotor speed; induction motor types, e.g. squirrel cage, wound rotor (slip ring)

_Constructional features_: cores, e.g. stator, rotor, laminations, spiders, materials; frame, e.g. cast, fabricated, end covers, materials; rotor, e.g. squirrel cage, wound type; stator, e.g. distributed windings, single layer, double layer; enclosure, e.g. cooling/ventilation, open, totally enclosed, drip proof, flameproof; shaft and fittings, e.g. bearings, slip rings, brushes, brush lifting gear enclosure ratings, e.g. Ingress Protection, BS 490, BS 5345

_Characteristics and calculations_: characteristics, e.g. frequency, poles, speed/load, torque/speed, torque/slip; calculations, e.g. speed, slip, starting current, load, torque, power, efficiency

2  Know how three-phase synchronous and synchronous-induction motors operate

_Principle of operation_: production of rotating magnetic field, e.g. distributed winding, salient pole, frequency, pole pairs, synchronous speed, effect of excitation; synchronous motor types, e.g. pony motor, synchronous-induction motor, synchronising; characteristics, e.g. open circuit, v-curves; reasons for calculations, e.g. speed, torque, leading/lagging power factor, power, efficiency

_Constructional features_: rotor, e.g. cylindrical, salient pole; stator, e.g. distributed windings, single layer, double layer; excitation methods, e.g. DC exciter, AC exciter, brushless

3  Understand the function and operation of motor starters and control gear

_Starters_: circuit diagrams and operation of induction motor types, e.g. direct on line (DOL), star-delta, autotransformer, soft start, rotor resistance; circuit diagrams and operation of synchronous motor types, e.g. pony motor, synchronous-induction motor, synchronising; effects of reduced voltage starting, e.g. current, starting torque; protection devices, e.g. short circuit, earth leakage, overload, interlocks, trips

_Control gear_: speed control, e.g. variable frequency, inverters, pulse width modulation (PWM); motor drives, e.g. DC transistor/thyristor, inverter types, braking, soft starting; programmable logic controllers, e.g. simple ladder logic
4 Understand a range of industrial applications for installing, commissioning and maintaining three-phase motors

Load characteristics: load characteristics and demands of machinery, e.g. centrifugal fans and pumps, compressors, machine tools, mechanical handlers, plastic extruders, lifts, hoists, conveyors

Ratings and calculations: electrical parameters, e.g. power, KVA, KVAR, power factor, voltage, current; mechanical parameters, e.g. power, speed, slip, torque, efficiency, gear ratios, volume, pressure, flow

Installation, commissioning and maintaining: installation procedures, e.g. foundations, mountings, insulation checks, rotation, couplings; commissioning procedures, e.g. starting, running, load test, temperature monitoring; maintenance procedures, e.g. rotor/bearing checks, lubrication, brushes, brush gear, control gear, insulation tests
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong></td>
<td>describe the principle of operation and the constructional features of a three-phase squirrel-cage and a three-phase wound rotor (slip ring) induction motor</td>
<td><strong>M1</strong> explain the production of a rotating magnetic field from a three-phase supply suitable for three-phase induction motors</td>
<td><strong>D1</strong> evaluate the speed control methods used for three-phase induction motors and explain the effects of changing speed on torque/slip characteristics</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>carry out calculations involving frequency, poles, speed, torque, power and efficiency for a three-phase induction motor from given data</td>
<td><strong>M2</strong> explain the variation of torque and slip for a three-phase induction motor using values from given data</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>describe the principle of operation, constructional features and excitation methods of a three-phase synchronous motor</td>
<td><strong>M3</strong> explain the methods of starting a three-phase synchronous motor and the effects of variation of excitation with reference to the v-curve characteristics</td>
<td></td>
</tr>
</tbody>
</table>
## Assessment and grading criteria

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</tr>
</thead>
<tbody>
<tr>
<td><strong>P4</strong> explain, with the aid of suitable circuit diagrams, the operation of two different reduced voltage starters for induction motors, one starting method for a synchronous motor, and a protection device for use with a three-phase induction motor</td>
<td><strong>M4</strong> justify the selection of a three-phase motor and its drive for a given application, using calculations involving electrical and mechanical parameters.</td>
<td><strong>D2</strong> analyse an installation, commissioning and maintenance process for a three-phase motor and its drives and suggest possible improvements.</td>
</tr>
<tr>
<td><strong>P5</strong> explain the control gear required for a three-phase induction motor and a three-phase synchronous motor</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> explain the characteristics of typical loads for four types of machinery driven by three-phase motors</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> select a suitable three-phase motor for a given application giving details of ratings, starter types and control gear requirements</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> explain the installation, commissioning and maintenance procedures for a three-phase motor.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

This unit could be assessed through the use of four assignments.

The first assignment could be about induction motors and cover criteria P1, P2, M1, M2, D1 and D2. A written task should be given to cover P1. Learners will need to consider the production of the rotating magnetic field when describing the principle of operation. They will also need to consider cores, frame, rotor, stator, enclosure and shaft and fittings when describing the constructional features.

Learners should be given data to use when carrying out the calculations required by P2. This data could be varied for each learner to aid authenticity, or the task could be time-constrained. A further task should be set asking them to explain the production of a rotating magnetic field and the variation of torque and slip using given values to achieve criteria M1 and M2 respectively. Learners’ evidence will be written and will include their calculations. For criterion D1, a task should be set that asks them to write a report that shows an evaluation of the speed and control methods, and explain the effects of changing speed on torque/slip characteristics.

The second assignment could cover synchronous motors and cover criteria P3 and M3. A written task could cover the construction, operation and excitation of synchronous motors. A practical exercise or demonstration could be done for starting and variation of excitation. From this information, learners can formulate relevant descriptions and explanations. Starting voltage, current and torque are useful parameters to be measured.

A third assignment on starting and control could cover criteria P4 and P5. While a written task could be used to cover both criteria, it would be more interesting for learners if they could operate starters and drives and take appropriate measurements. Explanation of the control gear could be as a result of stripping down or opening up starters, drives and other control gear. In doing so, it is important that learners also consider the effects of reduced voltage such as current and starting torque.

The fourth assignment on applications could cover criteria P6, P7, P8, M4 and D2. Tasks should require learners to refer to details of typical loads and machinery to be driven (P6). Learners must then consider the types of motor and control gear appropriate for driving different loads and select and describe the features (P7).

For M4, choices need to be supported by detailed calculations, with relevant justification of some depth using calculated parameters. The evaluation of speed control (D2) must be linked to the torque/slip characteristics and include details of more than one method, for example thyristor drives and inverter drives. A further written task could ask learners to describe the installation, commissioning and maintenance procedures for a three-phase motor (P8).

Manufacturers’ literature and specifications are a useful source of practical information for the above tasks.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, M1, M2, D1</td>
<td>Induction Motors</td>
<td>A technician needs to strip down, inspect and report on the operation of induction motors.</td>
<td>A report, including a set of written descriptions, the results of calculations and an explanation of the production of a rotating magnetic field and the variation of torque and slip.</td>
</tr>
<tr>
<td>P3, M3</td>
<td>Synchronous Motors</td>
<td>A technician needs to strip down, inspect and report on the operation of synchronous motors.</td>
<td>A written report, including descriptions based on practical demonstration of excitation methods.</td>
</tr>
<tr>
<td>P4, P5</td>
<td>Starters and Control Gear</td>
<td>A technician needs to show a new learner the operation of starters and control gear.</td>
<td>A written report.</td>
</tr>
<tr>
<td>P6, P7, P8, M4, D2</td>
<td>Applications of Three-Phase Motors</td>
<td>A technician has been asked to produce a report on the three-phase motors used in an industrial application in their workplace.</td>
<td>A written report based on a practical investigation or case study of local industrial applications.</td>
</tr>
</tbody>
</table>
Essential resources

Centres delivering this unit must have access to industrial standard three-phase electric motors, starting/control gear and associated drives. In addition, appropriate and adequate testing instruments and fault-finding assemblies should be provided. European and British Standards, health and safety and other publications should also be available.

Indicative reading for learners

Textbooks


Unit 42: Further Electrical Principles

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Electrical technicians need to apply practical and theoretical principles of electrical engineering to the development, manufacture and servicing of complex electrical and electronic systems.

They can expect to perform technical functions involved in assembling, installing, repairing and maintaining electrical equipment. These could include the calibration, prototyping, modification and general maintenance of electrical equipment in accordance with manufacturers’ instructions and company technical procedures.

Other tasks could include using electrical test equipment on various types of instruments, equipment and systems and replacing faulty components and parts using safe working practices and precision instruments.

The unit will extend learners’ understanding of simple direct current (DC) circuits that can be solved by Ohm’s law and Kirchhoff’s laws. This will require learners to apply advanced circuit analysis theorems such as Thévenin’s, Norton’s and the maximum power transfer theorems for DC networks.

Learners will develop their understanding of DC transients and of series and parallel alternating current (AC) circuits. They will consider series and parallel circuits that include resistors (R), inductors (L) and capacitors (C) in AC circuits.

The unit will also introduce learners to the theory and advantages of three-phase AC systems. This will include power measurements in a three-phase AC system and the construction and principles of operation of a three-phase AC induction motor.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Be able to apply direct current (DC) circuit analysis methods and consider the types, construction and characteristics of a DC motor and generator.
2. Understand the transient behaviour of resistor-capacitor (RC) and resistor-inductor (RL) DC circuits.
3. Be able to apply single-phase alternating current (AC) theory.
4. Be able to apply three-phase alternating current (AC) theory.
Unit content

1. Be able to apply direct current (DC) circuit analysis methods and consider the types, construction and characteristics of a DC motor and generator

   **Direct current (DC) circuit theorems:** Thévenin’s theorem, e.g. application of theorem to a parallel circuit having two sources of electromotive force (emf) and three resistors; Norton’s theorem, e.g. application of theorem to a parallel circuit having two sources of emf and three resistors; maximum power transfer theorem, e.g. application of theorem to a series circuit with a source of EMF, internal resistance and a load resistor; application to a more complex circuit where Thévenin needs to be applied first

   **Direct current (DC) motor:** type, e.g. shunt, series, compound; construction, e.g. windings, motor starter circuits, speed control (series resistance in the armature circuit); characteristics, e.g. EMF generated, torque, back emf, speed and power, efficiency

   **Direct current (DC) generator:** type, e.g. separately-excited, shunt, series compound; construction e.g. main frame or yolk, commutator, brushes, pole pieces, armature, field windings; characteristics, e.g. generated voltage/field current (open circuit characteristics), terminal voltage/load current (load characteristic), \( V = E - I_a R_a \)

2. Understand the transient behaviour of resistor-capacitor (RC) and resistor-inductor (RL) DC circuits

   **Transient behaviour of RC circuit:** variation of current and voltage with time when charging/discharging; time constant; graphical determination of growth and decay of voltage and current when charging/discharging; practical RC circuit to demonstrate transient behaviour; demonstrate the effect of the circuit time constant on a rectangular waveform, e.g. integrator and differentiator circuits; calculations, e.g. time constant, growth of capacitor voltage, initial and steady state values of current, decay of resistor voltage

   **Transient behaviour of RL circuit:** variation of current and voltage with time when connected/disconnected to a DC voltage source; time constant; graphical determination of growth and decay of current and voltage when connected/disconnected to a DC voltage source; practical RL circuit to demonstrate transient behaviour; calculations, e.g. time constant, growth of current, decay of induced voltage, current decay
3 Be able to apply single-phase alternating current (AC) theory

**Series R, L and C alternating current (AC) circuits:** current and phase angle in series combinations of RLC circuits (RL, RC, RLC); construction of phasor diagrams and relationship with voltage and impedance triangles for each of the three types of R, L and C combinations; power factor ($\cos \Phi$) and power triangle, e.g. apparent power ($S = VI$), true or active power ($P = V\cos \Phi$) and reactive power ($Q = V\sin \Phi$); conditions for series resonance e.g. inductive reactance equals capacitive reactance ($X_L = X_C$); Q factor (voltage magnification), e.g.

$$Q = \frac{V_L}{V}, \quad Q = \frac{1}{\sqrt{\frac{L}{C}}}$$

and its importance in high and low frequency circuits

**Parallel:** evaluation of the voltage, current and phase angle in parallel combinations of resistance, inductance and capacitance, e.g. RL, RC, LC and RLC; construction of phasor diagrams for impedance and phase angle; conditions for parallel resonance in an RLC circuit, e.g. supply current and voltage in phase; impedance at resonance, e.g. dynamic resistance $R_D = \frac{L}{CR}$; Q factor (current magnification), e.g. $Q = \frac{I_L}{I}$; filter circuits, e.g. high pass, low pass, band pass, band stop

4 Be able to apply three-phase alternating current (AC) theory

**Three-phase AC theory:** principles of single-phase and three-phase supplies, e.g. rotation of a single coil in a magnetic field, rotation of three identical coils fixed 120° apart in a magnetic field; star and delta methods of connection for power distribution systems; three and four wire systems; voltage relationships for star and delta connections under balanced conditions of load; calculation of power in balanced and unbalanced three-phase loads, e.g. $P = \sqrt{3}V_L I_L \cos \theta$, $P = 3I^2 R_p$

**Power measurements in a three-phase AC system:** e.g. delta system – one wattmeter method, star system – two wattmeter method

**Three-phase AC induction motor:** construction, e.g. stator, rotor, poles; principle of operation e.g. production of torque, synchronous speed, number of poles, starting methods, characteristics (speed/torque/efficiency versus current curves); concept of a rotating magnetic field, e.g. application of a three-phase supply to the stator windings, flux generated by each phase of the stator winding
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tbody>
<tr>
<td><strong>P1</strong> use DC circuit theorems to solve one circuit problem using Thévenin’s theorem, one using Norton’s theorem and one using the maximum power transfer theorem for DC networks</td>
<td></td>
<td><strong>M1</strong> explain the need for a DC motor starter and discuss its operation</td>
<td></td>
</tr>
<tr>
<td><strong>P2</strong> explain the construction and characteristics of a DC motor and a DC generator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong> explain the transient behaviour of current and voltage in an RC circuit, verifying through calculation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong> explain the transient behaviour of current and voltage in an RL circuit, verifying through calculation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong> use single-phase AC theory to calculate the current, voltage, impedance, power and phase angle in one of each of the series combinations of R, L and C circuits</td>
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## Assessment and grading criteria

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<tr>
<td><strong>P7</strong> use single-phase AC theory to calculate the input current, voltage, impedance and phase angle for a parallel combination of R, L and C</td>
<td><strong>M2</strong> discuss the advantages of power factor correction in an RLC circuit for a commercial consumer, giving a practical example by reference to specific calculations</td>
<td><strong>D1</strong> analyse the effects of resonance and Q factor in both a series RLC and a parallel RLC circuit</td>
</tr>
<tr>
<td><strong>P6</strong> investigate the performance of two filter circuits experimentally</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> use three-phase theory to explain the advantages of three-phase systems and star and delta methods of connection</td>
<td><strong>M3</strong> compare two different methods of power measurement in a three-phase system for both balanced and unbalanced loads.</td>
<td><strong>D2</strong> evaluate the performance of a three-phase induction motor by reference to electrical theory.</td>
</tr>
<tr>
<td><strong>P9</strong> carry out a practical power measurement on a three-phase system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P10</strong> describe the construction, principle of operation and concept of a rotating magnetic field of a three-phase AC inductor motor.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

A good deal of the assessment evidence for this unit can be achieved by practical experimentation, with real components and circuits and/or computer-based software packages where appropriate.

Because of the nature of the learning outcomes and unit content, up to six assessment instruments may be required. If a structured programme of practical work and short tests is also used, then the actual total number of pieces of assessed work could be even more than this. However, careful consideration should be given when designing the assessment not to place an unduly high assessment burden on learners or the tutor. Wherever possible, practical work should lead to a final product that can be assessed without further need for report writing.

Practical activities in the laboratory will need careful supervision. Tutors can capture this evidence by using appropriate records of observation and oral questioning for each learner.

For P1, learners will need to solve circuits involving Thévenin’s theorem, Norton’s theorem and the maximum power transfer theorem. Before attempting this criterion, learners could be introduced to the idea of a constant voltage source and a constant current source by using a suitable practical demonstration. Further development of this could lead to the link between Thévenin and Norton and then on to the use of Thévenin, before applying the maximum power transfer theorem.

P2 involves the explanation and comparison of a motor and a generator. Learners could possibly be shown actual motors/generators and be issued with incomplete diagrams for completion and annotation.

P3 and P4 require learners to explain the transient behaviour of current and voltage in an RC and an RL circuit both practically and theoretically. Use of a simple breadboarding technique for both criteria would be ideal here.

For both P5 and P7, an in-class assessment involving the evaluation of current, voltage, impedance and phase angle could be utilised. Learners could be given different circuit values and be encouraged to check their answers with a suitable software programme.

The investigation of the performance of two filter circuits (P6) could be achieved by using a signal generator with a low voltage output \( V_{IN} = IV \) connected to an RC network. Learners could then measure the output \( V_{OUT} \) as the frequency is raised from, for example, 100 Hz to 10 000 Hz.

P8 requires learners to explain the advantages of three-phase systems (for example smaller conductors, two available voltages). The latter of these leads into the two forms of connection (star and delta). Assessment could take the form of an incomplete handout to be submitted at the end of a lecture or film about the advantages and forms of connection.

P9 requires learners to carry out practical power measurements in three-phase systems. A suitable three-phase resistance load bank together with a three-phase, four wire low voltage supply and three wattmeters could be used to enable learners to measure the power using one, two and three wattmeters for the different configurations.
Evidence for P10 is likely to be in the form of an investigative report. Again, it may be helpful to give learners an incomplete diagram for them to complete and annotate. For the principles of operation and concept of a rotating magnetic field of a three-phase induction motor it may be necessary to include a number of key words (e.g. synchronous speed, pairs of poles) and point to one specific type of three-phase induction motor (e.g. squirrel-cage rotor).

All except the smallest of motors require some type of starter to prevent heavy currents being drawn from the supply on starting. M1 is intended to evaluate this requirement in detail and consider the need for a DC motor starter (e.g. DC faceplate starter) and to discuss its operation. It is expected that learners will draw from the work done at pass and produce a referenced technical report, supported by a suitably labelled diagram to aid their discussion of the operation.

For M2, learners need to discuss the advantages of power factor correction in an RLC circuit for a commercial consumer, giving a practical example by reference to specific calculations. These could include reduced cost to the consumer with reference to a practical example. This could follow a practical demonstration of how the supply current reduces on the introduction of power factor correction, but can increase if over-corrected. M3 could be linked to the practical carried out for P9.

The analysis of the effects of resonance and Q factor in both a series RLC and a parallel RLC circuit (D1) builds on and could be linked to P5 and P7. Evidence for D1 could also be provided by considering the difference in resonance frequency, for example when the value of the resistance is varied.

D2 requires learners to evaluate the performance of a three-phase induction motor by reference to electrical theory, for example squirrel cage by reference to electrical theory. This could be achieved practically by using appropriate experimental rigs that allow the learner to compare their results with the known characteristics for specific machines.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<th>Scenario</th>
<th>Assessment method</th>
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</thead>
<tbody>
<tr>
<td>P1, P2, M1</td>
<td>DC Circuit Analysis and Generators</td>
<td>An activity requiring learners to complete three tasks that together solve circuit problems, compare a DC motor and generator, and evaluate the performance of a three-phase induction motor.</td>
<td>A report containing solutions to circuit theorems and written responses about DC motor/generator and three-phase induction motor characteristics. Carried out under controlled conditions.</td>
</tr>
<tr>
<td>P3, P4</td>
<td>DC Transients</td>
<td>A written activity that requires learners to explain the transient behaviour of an RC and RL circuit with a numerical verification.</td>
<td>A report containing written responses about the transient behaviour of RC/RL circuits supported by numerical calculations carried out under controlled conditions.</td>
</tr>
<tr>
<td>P5, P7, M2, D1</td>
<td>AC Single-Phase Series And Parallel Circuits</td>
<td>A written activity requiring learners to carry out calculations relating to the behaviour of series and parallel R, L and C single-phase AC circuits.</td>
<td>A report containing the results of calculations to determine specific parameters of series and parallel R, L and C single-phase AC circuits carried out under controlled conditions.</td>
</tr>
<tr>
<td>P6</td>
<td>Filter Circuits</td>
<td>A practical investigation for learners to measure the response of two simple filter circuits.</td>
<td>A report containing written responses and graphical evidence regarding the response of simple filter circuits.</td>
</tr>
</tbody>
</table>
### Essential resources

Learners will need access to a well-equipped electrical/electronics laboratory with up-to-date instruments such as digital/analogue multimeters, function generators and oscilloscopes. Centres will also need to provide appropriate circuit components as identified in the unit content together with the means to physically construct circuits.

Centres are strongly advised to consider the provision of suitable hardware and software to enable the use of computer-based methods for circuit design and simulation.

### Indicative reading for learners

#### Textbooks

Bird J O – *Electrical and Electronic Principles and Technology* (Routledge, 2013)  
ISBN 9780415662857

Bird J O – *Electrical Circuit Theory and Technology* (Routledge, 2013)  
ISBN 9780415662864

Robertson C R – *Further Electrical and Electronic Principles* (Routledge, 2008)  
ISBN 9780750687478

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<table>
<thead>
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<th>Scenario</th>
<th>Assessment method</th>
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<tbody>
<tr>
<td>P8, P9, M3, D2</td>
<td>Three-phase AC Theory</td>
<td>A combined written and practical activity requiring learners to explain the advantages of three-phase systems, the star and delta method of connection followed by a practical power measurement with a comparison of two different methods for both balanced and unbalanced loads together with an evaluation of its performance.</td>
<td>A report containing written responses to the advantages of three-phase systems, an illustration of the methods of connection and measurements of the practical work carried out.</td>
</tr>
</tbody>
</table>

P10

<table>
<thead>
<tr>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-phase AC Induction Motor</td>
<td>A written activity describing the construction, operation and concept of a rotating magnetic field for a three-phase (AC) induction motor.</td>
<td>A report containing neat diagrams and descriptions relating to a three-phase (AC) induction motor.</td>
</tr>
</tbody>
</table>
Unit 43: Manufacturing Planning

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

There are many new technologies involved in planning the manufacturing of products, parts and components but many smaller companies still operate and work with traditional approaches.

This unit will give learners a good understanding of the basic techniques of manufacturing planning and an awareness of scheduling requirements. It introduces learners to different types of production and will give them an understanding of the stock holding policies that still exist in many engineering companies. Knowledge of the costs associated with holding stock can aid future manufacturing strategies and any related business improvement considerations.

Before learners develop a production plan, they are expected to have an understanding of the general aspects of planning and control and the techniques used to measure efficiency in a product manufacturing system. Some of these techniques could be explored in detail should learners show an added interest in this area.

Learners are required to produce a production plan from a given range of information in a product specification and prepare a production schedule to support the delivery of the production plan. This unit provides underpinning knowledge for a range of other units, particularly those associated with business improvement.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Understand the techniques and policies used to improve product manufacturing efficiency
2. Understand general aspects of planning and control
3. Be able to use a product specification to produce a production plan
4. Be able to produce a production schedule.
Unit content

1 Understand the techniques and policies used to improve product manufacturing efficiency

*Types of production:* jobbing; batch; cellular; flow; mass; automatic

*Stock holding policy:* types of inventory, e.g. materials, parts, components, tools, consumables, finished goods; stock holding costs, e.g. ordering/replenishment, holding, obsolescence; buffer stock; re-order levels; storage areas; economic order quantity, e.g. 

\[ Q = \frac{\sqrt{2Cr}}{Cc} \quad \text{or} \quad Q = \left( \frac{2Cr}{Cc} \right)^{\frac{1}{2}} \]

*Appropriate techniques:* e.g. method study, value analysis, job design (ergonomics, layout, safety); work measurement

2 Understand general aspects of planning and control

*Aspects of planning:* capacity measurement, e.g. machine hours, man hours, throughput, department hours; production planning; pre-production planning; other aspects, e.g. information technology, documentation, health and safety, environmental issues

*Control:* functions, e.g. production control, quality control

3 Be able to use a product specification to produce a production plan

*Product specification:* aspects relative to manufacturing and not the customer; type of information required for manufacture, e.g. engineering drawings, process description, make and assembly techniques and requirements, materials required, measurements, tolerances and other quality specifications

*Production plan:* consideration of a product specification and types of production; requirements (processes, materials required, quantities required, tools and equipment, labour required, estimated process times, quality checks)

4 Be able to produce a production schedule

*Production schedule:* based on the requirements identified within a production plan; presentation techniques, e.g. use of a Gantt chart, critical path network, line of balance technique; data, e.g. completion deadline, customer requirements, capacity available
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong></td>
<td>describe the six different types of production</td>
<td>explain the circumstances in which cellular production would be better than batch production</td>
<td>discuss the relationship between economic order quantities and stock holding costs</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>explain a stock holding policy for a given type of inventory</td>
<td>explain how you determined the economic order quantity</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>determine an economic order quantity from given data</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong></td>
<td>explain an appropriate technique used to improve product manufacturing efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P5</strong></td>
<td>explain the aspects of planning in manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong></td>
<td>explain functions of control used in manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong></td>
<td>use a product specification to produce a production plan</td>
<td>compare the importance of different types of information in a product specification when producing a production plan and schedule</td>
<td>evaluate the use of a production plan when preparing a production schedule and the dangers of the schedule not meeting stock holding requirements.</td>
</tr>
<tr>
<td><strong>P8</strong></td>
<td>explain the use of a production schedule</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong></td>
<td>produce a production schedule from a production plan and given data.</td>
<td>analyse how the use of presentation techniques can be used to overcome capacity and production planning problems.</td>
<td></td>
</tr>
</tbody>
</table>

P1, P2, P3, P4, P5, P6, P7, P8, P9, M1, M2, M3, M4, D1, D2
Essential guidance for tutors

Assessment

It is important that the assessment strategies used are designed to suit the needs of learners and any local industry requirements. Good assessment strategies need to be supported by the proper presentation of appropriate evidence. The portfolio should not contain course notes, research etc. unless it is part of the required evidence and assessment.

Work done through the use of case-study material can be used to generate evidence for learners’ portfolios. An integrated approach to this unit would be a suitable way for learners to gather evidence, particularly for learning outcomes 3 and 4.

To achieve a pass grade, learners should demonstrate knowledge of types of production, stocking policies and understanding techniques used to improve manufacturing efficiency. Learners are also expected to explain general aspects of planning and control and the use of a production schedule. They should then demonstrate the correct development of a production plan when using a product specification, a schedule and other data.

This unit could be assessed using three assignments. The first assignment could cover learning outcome 1 and its associated criteria (P1, P2, P3, P4, M1, M2 and D1), with a task set for each criterion. For P3, a range of data – such as ordering or replenishment costs per order ($C_r$), holding costs ($C_h$) and usage rate ($r$) – should be given to allow an economic order quantity ($Q$) to be determined. This could then be extended to include an explanation for M2 and a discussion of the relationship between economic order quantities against the costs involved in holding stock (D1).

Criteria P5 and P6 could be set in a second assignment as separate written tasks. A final assignment could be developed to cover P7, P8, P9, M3, M4 and D2. A product specification should be made available to each learner for them to use to develop a production plan. They could then be asked to produce a production schedule when given further data, such as completion time and capacity available. Standard templates for both the plan and schedule can be used as this would be similar to industrial practice.

Another task would then need to be given, asking learners to provide a written response when explaining the use of a production schedule. Further written tasks should also be included to cover M3, M4 and D1.

To achieve a merit grade, learners should explain what parts of the product specification are most important when developing a plan and schedule. A task for M1 could be given to build on the response given to criteria P1 in the first assignment. A task for M3 should be left until all pass criteria have been attempted and therefore be in the third and final assignment about planning and scheduling. They should also be able to analyse how information found in Gantt charts and critical path network documents could be used to identify and help overcome any over-capacity problems and how improvements can be made to the production plan (M4). This criteria requires a written task set in the final assignment.

To achieve a distinction grade, learners should demonstrate a comprehensive knowledge understanding and of manufacturing planning. Learners will confidently evaluate the development of a production schedule when using a production plan and other data in terms of whether that schedule will have an effect on stock holding requirements (D2).
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, P4, M1</td>
<td>Types of Production in Manufacturing Industries</td>
<td>A written activity requiring learners to look at a case study of real-life production and stock control.</td>
<td>Written responses to case study based questions about the key features of different production types and describing a stock holding policy and the techniques used to improve efficiency.</td>
</tr>
<tr>
<td>P5, P6</td>
<td>Product Specifications</td>
<td>A written assignment and oral questioning on developing a product specification for an existing product and designing a common specification template that accounts for control functions in production.</td>
<td>A whole group activity with learners creating a product specification for a real-world product they have access to and explaining product template for use in further assignments that explain planning and control aspects of production.</td>
</tr>
<tr>
<td>P7, P8, P9, M2, M3, D1</td>
<td>Product Planning and Scheduling</td>
<td>Presenting a production plan and schedule based on a product specification. Write up report on the presentation and production schedule.</td>
<td>Presentation and accompanying documents that explain the use of a production schedule and other data. Written report on presentation evaluating the use made of the production schedule and the presentation techniques used.</td>
</tr>
</tbody>
</table>
Essential resources

A range of production data and information as described in the unit content is needed for learning and assessment. Ideally, examples and data from industry will be provided and access to manufactured products will be required.

Indicative reading for learners

Textbooks


Unit introduction

For components to be manufactured to a required standard, the machines that produce them need to be correctly set up by technicians, ready for an operator to use. During this process, trial components are made to check accuracy and ensure a minimum amount of waste during production. Once satisfied that a machine’s parameters are correctly set, the technician would then brief the machine operator and the mass production of accurate components can begin.

The aim of this unit is to give learners a detailed understanding of the setting of secondary processing machines, including traditional machines (for example lathes and drilling machines) and others found in a more specialist workshop (for example spark or wire erosion methods). Learners’ ability to set a machine and brief an operator will stem from their knowledge of the machine itself and their ability to select and use the most appropriate work-holding devices and tooling.

The unit provides an opportunity for learners to examine a range of secondary processing machines, their set-up and the best use of work-holding devices and tools. Learners will need to gain an understanding of the features of the component to be made to enable them to effectively set up the machine and hand over to an operator.

Safety is an important issue to be considered when setting and using secondary processing machines. In this unit, learners will gain knowledge about, and demonstrate safe working practices when carrying out activities. They will also carry out checks for component accuracy and demonstrate this accuracy after setting a machine and when handing over to an operator.

With the knowledge and understanding gained from this unit, there are other opportunities for investigation of a wider range of secondary processing machines, their work-holding devices, tools and machine parameters.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Know how traditional and specialist secondary processing machines function.
2. Understand how work-holding devices, tools and machine parameters are set up to produce a range of components.
3. Be able to safely set up a secondary processing machine to accurately make a component.
4. Know how to produce trial components relevant to the use of a secondary processing machine before handing over to an operator.
Unit content

1 Know how traditional and specialist secondary processing machines function

Secondary processing machines: basic principles of operation; machine's suitability to manufacture given components; relevant safe working practices for each machine; machine terminology, e.g. cross slide, spindle, head stock, generation of shapes, forming of shapes; traditional secondary machining techniques, e.g. turning (centre lathe, capstan, turret, single-spindle automatic, multi-spindle automatic), milling (horizontal, vertical, universal), grinding (surface, cylindrical, centreless, universal, thread grinding, tool and cutter grinding, universal or purpose-built machines), drilling (single spindle, multi-spindle); specialist secondary machining techniques, e.g. boring (horizontal, vertical), electro discharge (spark erosion, wire erosion), honing and lapping (horizontal and vertical honing, rotary disc lapping, reciprocating machines)

2 Understand how work-holding devices, tools and machine parameters are set up to produce a range of components

Work holding: devices for traditional secondary machining techniques, e.g. chucks (hard or soft jaws, three or four jaw, collet, power, magnetic), fixtures and other machine specific devices for:

- turning (drive plate and centres, faceplates, magnetic or pneumatic devices, fixed steadies or travelling steadies)
- milling (clamping direct to machine table, pneumatic or magnetic table, machine vice, angle plate, vee block and clamps, indexing head/device, rotary table)
- grinding (centres, face plate, machine vices, clamps, angle plates, vee blocks, works rests, control stops, injector mechanisms, magnetic blocks, pots, arbors)
- drilling (clamping direct to machine table, machine vice, angle bracket, vee block and clamps, drill jigs, indexing device)

Devices for specialist secondary machining techniques, e.g. angle plate, vee block and clamps, other machine specific devices for:

- boring (clamping direct to machine table, machine vice, pneumatic or magnetic table, indexing/rotary device)
- electrical discharge machining (clamping direct to machine table, machine vice, pneumatic or magnetic table, ancillary indexing device)
- honing and lapping (pots, magnetic blocks, face plate)
**Tools**: materials and form, e.g. solid high-speed steel, brazed tungsten carbide, indexable tips, electrode material, abrasive stone, composite wheels; tools for traditional secondary machining techniques, e.g. for:

- turning (turning tools, facing tools, form tools, parting-off tools, thread chaser, single-point threading, boring bars, recessing tools, centre drills, twist/core drills, solid reamers, expanding reamers, taps, dies, knurling tool)
- milling (face mills, slab mills/cylindrical cutters, side and face cutters, slotting cutters, slitting saws, profile cutters, twist drills, boring tools, end mills, slot drills)
- grinding (soft wheel, hard wheel, cup, flaring cup, straight sided wheel, recessed wheel, double recessed wheel, dish, saucer, disc, segmented)
- drilling (drill bit, flat-bottomed drill, counterboring tool, countersinking tool, centre drill, spot facing tool, reamer, tap)

Tools for specialist secondary machining techniques, e.g. for:

- boring (boring tool, facing, turning, recessing, chamfering or radii, forming, twist drill, tap, reamer, milling cutter)
- electrical discharge machining (plain electrode, profile electrode, hollow electrode, wire)
- honing and lapping (mandrel, wedge, honing stone, lapping disc/pad)

**Machine parameters**: position of workpiece; position of tools in relationship to workpiece; cutting fluid/dielectric flow rate; position and operation of machine guards/safety mechanisms; parameters for different traditional secondary processing techniques, e.g. for:

- turning (threading/profile/taper mechanisms, workpiece revolutions per minute, linear feed rate, depth of cut for roughing and finishing)
- milling (linear/table feed rate, milling cutter revolutions per minute, depth of cut for roughing and finishing)
- grinding (linear/table feed rate, depth of cut for roughing and finishing, cross feed, dressing of wheels)
- drilling (tooling revolutions per minute, linear feed rate, swarf clearance)

Parameters for different specialist secondary processing techniques, e.g. for:

- boring (set up and tooling relative to datum, feed rate, cutter/tool revolutions per minute, depth of cut for roughing and finishing)
- electrical discharge machining (electrical conditions, wire tension, wire speed, alignment of electrodes and wire, ventilation and fume extraction, filtration)
- honing and lapping (revolutions per minute or reciprocating speed, stroke length, stroke overrun length, stroke speed, stone or disc pressure)
Features of the component: materials, e.g. ferrous, non-ferrous, non-metallic; holes, e.g. drilled, bored (parallel or tapered), reamed, threaded, blind, through, counterbored, flat bottomed; relevant component features produced using traditional secondary processing techniques, e.g. for:

- turning operations (flat faces, parallel diameters, stepped diameters, tapered diameters, profile forms, external threads, eccentric features, parting off, chamfers, knurls or special finishes, grooves, undercuts)
- milling operations (flat faces, square faces, parallel faces, angular faces, steps/shoulders, open ended slots, enclosed slots, recesses, tee slots, profile forms, serrations, indexed or rotated forms, special forms)
- grinding operations (flat faces, vertical faces, parallel faces, faces square to each other, shoulders and faces, slots, parallel diameters, tapered diameters, profiles forms, other thread forms, vee-form threads, right-hand threads, single start threads, multi-start threads, external threads, angular faces)
- drilling operations (countersinking, spot facing, holes)

Relevant component features produced using specialist secondary processing techniques, e.g. for:

- boring operations (internal profiles; external profiles, e.g. external diameters, grooves/recesses, chamfers/radii, flat faces, square faces, parallel faces, angular faces, slots, index or rotated forms)
- electrical discharge machining operations (holes; faces – flat, square, parallel, angular; forms – concave, convex, profile, square/rectangular; other features – threads, engraving, cavities, radii/arcs, slots)
- honing and lapping operations (honing holes; lapping faces, e.g. flat, parallel, angular)

3 Be able to safely set up a secondary processing machine to accurately make a component

Set up: machine guards in place; select and set tooling; checking tool/wheel condition; holding components securely without distortion; selection and use of suitable work-holding device(s); set machine parameters to manufacture given component

Safe working: safe set-up of moving parts, e.g. setting stops, preventing tooling clashes; use of machine guards to protect operator and others; choice and handling of cutting fluids/dielectric flow rate; checks for insecure components; facilities for emergency stop and machine isolation; identification of appropriate protective clothing and equipment; housekeeping arrangements (work area clean and tidy); safe working practices relevant to specific secondary processing technique, e.g. for:

- turning (handling turning tools, airborne particles, tool breakage, swarf disposal)
- milling (handling milling cutters, cutter breakage, swarf disposal, backlash in machine slides)
- boring (handling tools and cutters, airborne particles, tool breakage)
- electrical discharge machining (electrical components, handling dielectrics, fumes, handling and storing electrodes and wires)
• grinding (handling grinding wheels, sparks/airborne particles, bursting wheels)
• drilling (handling drills, taps and reamers, tool breakage, swarf disposal)
• honing and lapping (handling and storing stones, airborne particles)

Checks for accuracy: components to be free from burrs and sharp edges; use of appropriate tools and instruments; checks for dimensional accuracy and surface texture; checks relevant to specific secondary machining technique e.g. for:

• turning (components to be free from false tool cuts, dimensional tolerance equivalent to BS/ISO, surface finish 63 \( \mu \)m or 1.6 \( \mu \)m, reamed or bored holes within H8, screw threads BS medium fit, angles within +/- 0.5 degree)
• milling (components to be free from false tool cuts, dimensional tolerance equivalent to BS/ISO surface finish 63 \( \mu \)m or 1.6 \( \mu \)m, flatness and squareness within 0.001 inch per inch or 0.125 mm per 25 mm, angles within +/- 0.5 degree)
• boring (components to be free from false tool cuts, dimensional tolerance equivalent to BS/ISO surface finish 63 \( \mu \)m or 1.6 \( \mu \)m, flatness and squareness within 0.005 inch per inch or 0.025 mm per 25 mm, angles within +/- 0.5 degree, bored holes within H8)
• electrical discharge machining (components to be free from false starts; dimensional tolerance to BS/ISO, surface texture 32 \( \mu \)m or 0.8 \( \mu \)m or 18 VDI; checks, e.g. for parallelism, angle/taper, squareness, profile)
• grinding (tolerance to BS/ISO surface texture 8 \( \mu \)m or 0.2 \( \mu \)m, free from false grind cuts)
• drilling (components to be free from false tool cuts, dimensional tolerance equivalent to BS/ISO, surface finish 63 \( \mu \)m or 1.6 \( \mu \)m, reamed holes within H8, screw threads BS medium fit)
• honing and lapping (components to be free from stone/disc marks; dimensional tolerance equivalent to BS/ISO; surface finish 8 \( \mu \)m or 0.2 \( \mu \)m; honed components checked for parallelism and ovality/lobbing; lapped components checked for parallelism and flatness)

4 Know how to produce trial components relevant to the use of a secondary processing machine before handing over to an operator

Trial components: to meet the features and accuracy required by the specification

Use of machine: correct use of work holding devices; tools; machine parameters and safety

Handing over: correct set-up; supplies of components and consumables; machine functions correctly; quality requirements; consideration of safe working

Handover procedures: demonstrating operation; explaining the key stages; highlighting critical areas, e.g. safety, specific tolerances, finishes; observing operator and correcting any errors; ensuring operator is working safely and competently before leaving; periodic checks of machine and operator performance
**Assessment and grading criteria**

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
<thead>
<tr>
<th>Assessment and grading criteria</th>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong></td>
<td><strong>M1</strong> explain the effects of using an inappropriate work-holding device when setting up a secondary processing machine</td>
<td><strong>D1</strong> justify the choice of a work-holding device for a given component when setting up a secondary processing machine</td>
<td></td>
</tr>
<tr>
<td>describe how four different secondary processing machines function when machining a given component for each</td>
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</tr>
<tr>
<td><strong>P2</strong></td>
<td><strong>M2</strong> explain the importance of setting machine parameters correctly to produce accurate features on a component produced by a secondary processing machine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>explain how work-holding devices and tools are used on four different secondary processing machines to manufacture a different given component for each machine</td>
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<tr>
<td><strong>P3</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>explain how a range of machine parameters are set up to produce required features on components machined on four different secondary processing machines</td>
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<tr>
<td><strong>P4</strong></td>
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<tr>
<td>set up a secondary processing machine to safely produce a given component</td>
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<tr>
<td><strong>P5</strong></td>
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<tr>
<td>carry out checks for accuracy of a given component during the set-up of a secondary processing machine</td>
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</tr>
</tbody>
</table>
## Assessment and grading criteria

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<tbody>
<tr>
<td><strong>P6</strong> explain how to produce trial components on a secondary processing machine</td>
<td><strong>M3</strong> explain the impact of producing trial components and correct handover procedures on the operator being able to continuously produce accurate components.</td>
<td><strong>D2</strong> evaluate the impact that aspects of working safely have on the effectiveness and accuracy of setting up a secondary processing machine.</td>
</tr>
<tr>
<td><strong>P7</strong> explain how to hand over a secondary processing machine to an operator, including a description of the handover procedures used.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment evidence for this unit is likely to be gained from a mixture of written tasks and practical process evidence (witness statements/observation records).

To achieve a pass grade, learners must demonstrate knowledge of a range of different secondary processing machines and their techniques when carrying out set-up procedures. Both traditional and specialist techniques need to be covered. This means that learners need to know set up procedures for at least one technique from each range and an overall total of four.

Assessment of the procedure of actually setting up a machine, the knowledge required to prove the process by making trial components and handing over to an operator is restricted to one secondary processing machine, which can be either traditional or specialist. Centres and learners should pick the one most suitable for individual needs, considering any work-based learning expectations.

To achieve a merit grade, learners will need to demonstrate that they can explain some of the effects of using an inappropriate work-holding device when setting up a secondary processing machine. This could be achieved through the selection of appropriate work-holding devices for P2, together with learners demonstrating an appreciation of the possible effects of an inappropriate device. In addition, learners are required to explain the importance of producing accurate features on components, M2, that have been produced by a secondary processing machine. They also have to explain the importance of setting machine parameters correctly. For example, if the depth of cut and/or feed rate in a turning operation is not set correctly, then the component is likely to have an out of tolerance surface finish and not be free from false tool cuts.

Finally, learners need to explain the impact of producing trial components and correct handover procedures on the operator being able to continuously produce accurate components. For example, if trial components are meeting the correct accuracy checks then the ‘setter’ will be confident when demonstrating to the operator the procedures to follow and the correct tolerance and finish requirements explained more easily to the operator. The required evidence for these criteria is likely to be in the form of a written response to tasks set for the learner.

To achieve a distinction grade, learners will need to justify their choice of a work-holding device for a given component when setting up a secondary processing machine. This machine is likely to be one from their chosen skill route. Judgement needs to be made as to whether the device used would succeed and whether it is likely to meet the needs and features of the component, alignment and use of the tooling and tool-component interface.

They also need to evaluate the impact of working safely on the effectiveness and accuracy of setting up a secondary processing machine. They need to consider whether the use of the safety equipment hampers the set-up process. Again, the required evidence for these criteria is likely to be in the form of a written response to tasks set for the learner.

Wherever possible, it is important to maximise the opportunities for assessment through practical tasks. A possible scenario would be to use a total of three assignments. It may be best to set a practical assignment as the first of these. This could be to set up a secondary processing machine (P4) and carry out checks for accuracy (P5). Evidence for these criteria could be in the form of annotated photographs, observation record/witness statement(s), notes and sketches produced by learners that capture the processes carried out.
Learners will also need to maintain a record of all measurements taken and the action taken to correct any errors in the set up to complete the requirements of P5.

Following the practical, learners could then prepare a written report on how this secondary machining process functions and is set up. This could then be used to cover one of the four different machines required for P1, P2 and P3. It may also be the best opportunity to work towards the merit and distinction criteria M1, M2 and D1.

The second assignment could follow on from the practical activities and involve learners preparing a report on the machining process used in assignment 1. They would also need to research and report on three more machines to generate the evidence required for P1, P2 and P3. The tasks undertaken should make it clear what secondary processing machines are to be covered (this could be set by the tutor or could be decided through learner choice).

To meet the requirements of the unit content for outcomes 1 and 2, both traditional and specialist techniques need to be covered. However, as long as at least one of each type is covered then the other two can be either traditional or specialist machines. When choosing from the examples listed in the unit content, for example, turning (centre lathe, capstan, turret, single-spindle automatic, multi-spindle automatic), it would be sufficient to select from any one of the machines listed, for example for a turning machine – use of a single-spindle automatic. This applies equally to the other aspects of unit content where examples are given.

The choice from these lists will be solely determined by the component being machined. For example, work holding devices for turning lists drive plate and centres, faceplates, magnetic or pneumatic devices, fixed steadies or travelling steadies. If the component only requires mounting on a faceplate then this would be sufficient. However, when choosing components centres need to take care to ensure the use of a reasonable range of techniques. For example, if all the components, for all four machines selected could be simply held in a three-jaw chuck to complete all operations, then this would be considered insufficient.

The last assignment could ask learners to explain how trial components are produced (P6) and how to handover a secondary processing machine to an operator (P7). The assignment could also provide an opportunity to explain the impact of producing trial components and the impact of correct handover procedures on the operator being able to continuously produce accurate components (M3). It could also evaluate the impact of working safely on the effectiveness and accuracy of setting up a secondary processing machine (D2). See earlier examples of what is expected for criteria M3 and D2; remember that the explanation and evaluation are likely to be a consideration of the experience of the practical work carried out in the first assignment.

Although simulated or practical activities would be the preferred means of capturing evidence for P6 and P7, it is accepted that this might not always be possible or realistic for a number of reasons. If a simulation is possible then for P7 it may be best if the tutor takes the role of the operator. For both P6 and P7 process evidence (records of observation and oral questioning) could be used. This process evidence could then be supplemented/ supported by the product evidence that will be available from the activities e.g. the trial components, learners’ own preparation notes before handover and their own records of the actual handover process.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
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<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4, P5</td>
<td>Producing Components Using Secondary Processing Techniques</td>
<td>Learners are required to produce a component using a secondary processing machine and check it for accuracy.</td>
<td>A practical assignment evidenced through photographs, tutor observation records and learners’ notes.</td>
</tr>
<tr>
<td>P1, P2, P3, M1, M2, D1</td>
<td>Investigating Secondary Processing Machines</td>
<td>Learners need to prepare an information leaflet giving details of four different secondary processing machines.</td>
<td>A written report detailing how each secondary processing machine functions, and the work-holding devices, tools and machine parameters associated with each.</td>
</tr>
<tr>
<td>P6, P7, M3, D2</td>
<td>Producing Trial Components and Handing Over Secondary Processing Machines</td>
<td>Learners explain to a new member of staff how to produce a trial component and correctly hand over a secondary processing machine.</td>
<td>A written report detailing how to produce trial components and the correct handover procedures for a secondary processing machine.</td>
</tr>
</tbody>
</table>
Essential resources

To meet the needs of this unit it is essential that the centre has, or has access to some if not all of the range of machines specified in the unit content. This should include at least one specialist secondary processing machine. All auxiliary equipment such as that required for measuring accuracy should also be made available.

Indicative reading for learners

Textbooks


Kalpakjian, Serope – *Studyguide for Manufacturing Engineering & Technology* (Cram101 Textbook Reviews) ISBN 9789810694067
Unit 45: Business Operations in Engineering

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Engineers are employed in a range of businesses in the primary, secondary and tertiary sectors. Their knowledge and skills are used to carry out a variety of specific functions that solve the needs of businesses and contribute to their commercial success. By making effective use of their engineers’ expertise, organisations can secure competitive advantage, whether they be a small owner-managed company or a large limited company with many shareholders.

For anyone considering a career in engineering, it is important to have an understanding of how an engineering business operates and its position in society. This unit will develop learners’ understanding of business, the engineering industry and the effect of engineering on the environment. It will help give learners a firm foundation for employment in the engineering sector and an understanding of the organisational, financial, legal, social and environmental constraints in which an engineering company operates.

The unit will enable learners to examine an engineering company in detail. This could be either the one in which they are employed or one in an engineering sector in which they may look for employment. Learners will understand how the company operates, the factors that impact on the business and the importance of a cost-effective output. This will include an examination of the engineering functions of the company and the importance of communication and information flow in the business. This is set within a study of how external factors and the economic environment impact on the company.

Learners will examine relevant legislation and how it can place considerable constraints on the way that a typical engineering company is required to operate. A company cannot survive if it is not profitable and the unit allows learners to consider the use and implication of costing techniques on the sustainability of a particular engineering activity.

Note that the use of ’e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ’e.g.’ needs to be taught or assessed.
Learning outcomes

On completion of this unit a learner should:

1. Understand how an engineering company operates
2. Understand how external factors and the economic environment can affect the operation of an engineering company
3. Know how legislation, regulation and other constraints impact on the operation of engineering businesses
4. Be able to apply costing techniques to determine the cost effectiveness of an engineering activity.
Unit content

1 Understand how an engineering company operates

   Sectors: primary, e.g. oil, gas, agriculture; secondary, e.g. chemical, manufacturing, automotive, aerospace, marine, sports; tertiary, e.g. energy distribution, nuclear technologies, waste management, water services, building services, civil, construction, structural, health, telecommunications

   Engineering functions: e.g. research and development (R&D), design, manufacture, materials supply and control, production planning and control, installation, commissioning, maintenance, technical support, technical sales, project planning and management, quality assurance

   Organisational types: size, e.g. micro, small, medium, large; status, e.g. sole trader, partnership, public (plc), private (ltd), new, established, charitable, not for profit; structure, e.g. owner-manager, boards, committees, governors, hierarchical, flat, matrix

   Information flow: internal systems, e.g. lines of communication, working procedures, e-systems, integrated systems; people involved, e.g. supervisor, other employees, customers, suppliers; types of information, e.g. work instructions (such as operation sheets, engineering drawings, circuit diagrams), work in progress records, stock/orders/sales; work ethics of communication, e.g. confidentiality, integrity, respect

2 Understand how external factors and the economic environment can affect the operation of an engineering company

   External factors: factors to consider, e.g. markets, consumers, demographic and social trends, competitive products/services/organisations, customer/client relationships, innovation and technological change, availability of sustainable resources

   Economic environment: measures, e.g. gross national product (GNP), gross domestic product (GDP), balance of payments; location, e.g. local economy, regional and national economy (such as Regional Development Agency, local/regional skills targets); economic variables, e.g. interest rates, exchange rates
3 **Know how legislation, regulation and other constraints impact on the operation of engineering businesses**


*Environmental constraints*: e.g. sustainability, environmental impact, use of renewable energy resources, carbon footprint, recycling, product end of life strategy

*Social constraints*: e.g. employment levels, workforce skill levels and training requirements, opportunities for self-improvement and progression, motivation, impact of outsourcing

4 **Be able to apply costing techniques to determine the cost effectiveness of an engineering activity**

*Costing techniques*: income; expenditure; profit/loss; cost control, e.g. direct cost, indirect cost, fixed cost, variable cost, contribution, marginal costing; assets, e.g. investment and value of fixed assets, depreciation of fixed assets

*Make-or-buy decisions*: e.g. break-even point, investment appraisal, return on investment, pay-back time, financial risk, development costs
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

| Assessment and grading criteria | To achieve a pass grade the evidence must show that the learner is able to: | To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to: | To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to: |
|---------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| **P1**                          | explain the functions carried out by different engineering companies in the sectors in which they operate | **M1** discuss how improvements in information flow could enhance the functional activities of an engineering company | **D1** evaluate the information flow through an engineering company in relation to an engineering activity |
| **P2**                          | explain the organisational types of three given engineering companies | | |
| **P3**                          | outline how information flows through an engineering company in relation to an engineering activity | | |
| **P4**                          | explain how external factors and the economic environment affect the way in which an engineering company operates | **M2** discuss the impact of relevant legislation on a specific operation in a typical engineering company in terms of benefits and limitations | **D2** evaluate the importance and possible effect of the external factors that directly impact on an engineering company. |
| **P5**                          | describe the legislation and regulations that impact on the way an engineering business operates | | |
| **P6**                          | describe the environmental and social constraints that impact on the way an engineering business operates | | |
### Assessment and grading criteria

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<tr>
<td><strong>P7</strong> carry out costing techniques to determine the cost effectiveness of an engineering activity</td>
<td><strong>M3</strong> demonstrate how the cost effectiveness of an engineering activity could be improved.</td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> carry out costing techniques to reach a make-or-buy decision for a given product.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

It is likely that the assessment evidence for pass criteria P1 and P2 could be produced through the study of three separate engineering companies. One of these could be the company in which the learner is employed, with the others through case study or relevant research of companies chosen either by the learner or the tutor. It is important to ensure an opportunity for activity in all three sectors is given collectively across the three companies studied. Evidence for criteria P3, P4, P5 and P6 could be produced through the study of a single engineering company, again likely to be one chosen by the learner. The remaining pass criteria (P7 and P8) lend themselves to a controlled and time-constrained activity. Although opportunities to carry out costing exercises in a real environment may be used, it may be that issues of business confidentiality will prevent this.

This unit could be assessed using three assignments. The first assignment could assess criteria P1, P2 and P3 together with M1 and D1. Information should be given about three separate engineering companies, real or fictitious, ideally one from each sector (primary, secondary and tertiary). The functions that the companies carry out can be simplified, such as designing a solution to an engineering problem or installing a machine. Other information should be given about the size and structure of the organisations.

Work-based learners may wish to use their own company to satisfy part of each criteria, although they will need data on a further two organisations to fulfil the criteria. Written tasks could be given and the evidence is also likely to be in written format.

For P2, sketches may also help to explain organisational structures. For P3, learners need to be able to explain how functions within a business are able to communicate effectively to support business strategies in relation to an engineering activity (for example the link between design and technical sales, manufacturing and material/component supply). This will link to the content section on information flow, where learners need to explain the internal systems, people involved, types of information and work ethics of communication relevant to a specific activity within an engineering company.

A second assignment should require learners to investigate how external factors and the economic environment (P4), legislation and regulations (P5), and environmental and social constraints (P6) impact on the overall operation of an engineering business. It is sensible to also include criteria M2 and D2 in this assignment.

The evidence for the last two pass criteria (P7 and P8) could be gathered through a third assignment involving a costing exercise based on the engineering activity considered in P3. For example, this could involve the use of costing techniques to determine the cost effectiveness of the product/service and then looking at a make or buy decision for part of or the whole product/service. If this is not realistic or appropriate then separate tasks may be necessary. The engineering activity considered in the criteria P3 and P7 could, for example, be the manufacture of a product or the provision of a service. In either case, centres need to ensure that the relevant data is available to cover all aspects of the content, although the product or service itself does not need to be overly complex. A task could then be set to complete a make or buy decision (P8). Criterion M3 is also best linked to this assignment.
To achieve a merit grade, learners will need to apply evaluative skills to discuss how improvements in information flow could enhance the functional activities of an engineering company (M1). This could be a natural extension to work carried out for P1, P2 and P3. Learners should discuss the impact of legislation on a specific operation in a typical engineering company (M2). This has a link with the criterion P5, which considers legislation in a broader context for the company. For merit, learners need to analytically apply the understanding they have gained at pass level to consider the impact of legislation in terms of benefit (for example reduced risk to employees and therefore improved safety record) and limitations (for example increase in production cycle times and therefore increased costs) for the operation considered. Finally, to achieve the last merit criterion M3, learners should consider the costing exercise carried out for P7 and P8 and explain how the cost effectiveness of the engineering activity could be improved or the make-or-buy decision made more conclusive or even amended.

To achieve a distinction grade, learners should focus on a specific activity and evaluate the information flow through an engineering company in support of it (D1). This links to P2 and P3, where learners described organisational types and explained the information flow for an activity and with M1 their ability to consider improvements. The evaluation for D1 should consider the key aspects of the information flow, how it impacts on the specific activity and other functional activities of the company, plus any issues in terms of problems encountered or opportunities for improvement. As such this could be in the first assignment. To achieve D2, learners should evaluate the importance and possible effects of the external factors that directly impact on an engineering company. Learners will need to use their general understanding of external factors from P4 but at this level begin to take an analytical view of the relative importance and the direct effects on the business.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, M1, D1</td>
<td>Types and Operation of Engineering Businesses</td>
<td>An activity requiring learners to carry out research based on actual engineering companies. These companies will be involved in a range of business activities, and have different management structures and operating methods.</td>
<td>A portfolio containing written responses and flow diagrams based on primary and secondary research data. Carried out under controlled conditions. This activity could be supported by a PowerPoint presentation.</td>
</tr>
<tr>
<td>P4, P5, P6, M2, D2</td>
<td>External Factors and Legislation that Affect the Operation of an Engineering Company</td>
<td>An activity to investigate the external factors and pressures that can affect the profitability of businesses. It involves finding out about economic, legislative and environmental constraints in the context of a given engineering company.</td>
<td>A portfolio containing written responses to a number of defined activities. Carried out under controlled conditions. This activity could be supported by a PowerPoint presentation. This assessment could be delivered in two parts – small group research activity followed by a summative test.</td>
</tr>
<tr>
<td>P7, P8, M3</td>
<td>Assessing the Cost and Viability of an Engineering Activity</td>
<td>An investigative activity involving calculation and decision making supported by reflective writing and, where appropriate, verbal presentation.</td>
<td>A portfolio containing spreadsheets and written commentary carried out under controlled conditions. This activity could be supported by a PowerPoint presentation.</td>
</tr>
</tbody>
</table>
Essential resources

For this unit, learners require access to sufficient data on engineering companies. This can be in the form of case studies, industry visits or data available through learners’ employers.

Indicative reading for learners

Textbooks


Unit 46: Industrial Plant and Process Control

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Modern industrial plant would fail to operate effectively without appropriate process control systems and methods. Engineers play a vital role in designing, installing and operating such systems.

The aim of this unit is to introduce learners to the principles and techniques involved in the control of industrial process plants. The methods of process control are investigated, along with the industrial techniques that are employed to ensure that plant is controlled to meet given specifications.

The unit starts by considering the basic principles of control in terms of open- and closed-loop systems and the elements that are required as part of the loop. Further areas of closed-loop control are discussed and simple analysis techniques are considered.

Having identified a control system, the unit then considers the main controller types that are available. Emphasis is placed on the widely used two-step and three-term controllers. These controllers are examined in some depth with opportunities to extend knowledge of controllers through standard tuning methods.

Modern large industrial process plants are controlled using hierarchical control systems. This unit allows learners to consider hierarchical control strategies such as supervisory control and distributed control systems. The philosophies of these systems are discussed and reference to the physical structure is covered.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Understand the characteristics of process control systems
2. Know about common modes of control and their effect on control system performance
3. Be able to apply tuning methods to three-term controllers to improve control system performance
4. Understand hierarchical and advanced process control systems.
Unit content

1 Understand the characteristics of process control systems

System components: block diagrams; control loops, e.g. open, closed; accuracy and stability; elements, e.g. detecting, measuring, comparing, controlling, correcting

Transfer functions: block diagrams; transfer functions for simple closed-loop systems derived; closed-loop gain determined using derived transfer function; block diagram reduction techniques

System characteristics: inherent regulation; time constant; initial reaction rate; exponential growth and decay, e.g. equations (simple first order) for process systems, curves; lags, e.g. transfer, distance velocity, dead time; measurement of process dead time

2 Know about common modes of control and their effect on control system performance

Two-step control and terminology: applications of two-step control, e.g. temperature control, level control; definition of two-step control; functional attributes, e.g. effect of process lag, overlap, effect of the degree of overlap on process response

Three-term control and terminology: applications of three-term control, e.g. flow rate control, positional control; types of control (proportional (P), integral (I), derivative (D), proportional-integral-derivative (PID))

Three-term control parameters and system response: responses, e.g. under P control, under PI control, under PID control; parameters, e.g. proportional band, proportional gain, integral gain, integral action time, derivative gain, derivative action time

3 Be able to apply tuning methods to three-term controllers to improve control system performance

Tuning methods: methods (process reaction curve, ultimate cycle, frequency response); plant under three-term control, e.g. flow rate control, positional control

4 Understand hierarchical and advanced process control systems

Hierarchical control: pyramid of control, process instrumentation layer, supervisory layer, management layer

Types of hierarchical control systems: applications of distributed control systems (DCS), e.g. petrochemical, nuclear, paper mill; architecture of DCS; multi-loop structure, e.g. plant interfaces, process managers, operator stations, history modules, control networks, management networks; applications of supervisory control and data acquisition (SCADA), e.g. machine control, assembly line production, sequential manufacture; architecture of SCADA, e.g. remote terminal units, programmable logic controllers, control networks, remote input/output, supervisor stations

Advanced control: cascade control; feed-forward control (applications and improvement of response time)
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>P1</strong></td>
<td>describe the main system components of a given process control system</td>
<td><strong>M1</strong></td>
<td>design a block diagram of a single closed-loop process control system to meet a given specification in terms of transfer function and system characteristics</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>explain the operation of a given process control system using block diagrams and transfer functions</td>
<td><strong>D1</strong></td>
<td>evaluate the extent to which the design meets the given specification</td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>explain process control system characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong></td>
<td>describe the functional attributes of a two-step controller, using controller terminology for a given application</td>
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<td></td>
</tr>
<tr>
<td><strong>P5</strong></td>
<td>describe an application of a three-term controller and the meaning of the four types of control</td>
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<td></td>
</tr>
<tr>
<td><strong>P6</strong></td>
<td>record the control system output responses relating to various values of three-term parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong></td>
<td>use three tuning methods to improve the performance of plant under three-term control</td>
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<td></td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>P8</strong> explain the pyramid of control for hierarchical control systems</td>
<td><strong>M2</strong> design a structure for a hierarchical control system, explaining how it meets a given requirement.</td>
<td><strong>D1</strong> evaluate the performance of a given process control system.</td>
</tr>
<tr>
<td><strong>P9</strong> describe two types of hierarchical control system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P10</strong> explain how two types of advanced control can improve plant performance.</td>
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<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment evidence for pass criteria P1, P2 and P3 could be produced through a written assignment. After describing the main components (P1) learners would need to consider a single closed-loop process control system and explain its operation. Block diagrams and transfer function calculations should be used to aid the explanation (P2). The use of simulation software in the assignment should also be encouraged to identify the system characteristics of the single-control loop. Hard copy printouts using the simulation software could form part of the evidence for P3 in the assignment.

Assessment evidence for pass criteria P4, P5 and P6 could be produced through a combination of a practical assignment and written tasks that will enable learners to describe the functional attributes of a two-step controller (P4) through a practical application (e.g. the control of liquid level within a tank). The assessment could then require learners to control liquid flow or shaft position (P5) and record the responses of the system under three term control.

Various three-term controller parameters should be used in the practical activity and context given, and a report produced concluding on the various response results (P6). The practical activity could be extended to include the tuning of a three-term controller to improve the performance of the plant (P7). All three tuning methods should be used and conclusions clearly stated, identifying the most suitable technique in terms of final system improvement.

Assessment evidence for pass criteria P8 and P9 could be produced through a written assignment relating to case studies of hierarchical control systems. The assignment could require learners to explain and describe the operation of given schematics of an industrial SCADA and a DCS. Evidence for pass criteria P10 could also be considered in the same assignment. Learners could be asked to consider a single loop in one of the given hierarchical systems and provide a written explanation of how both feed forward and cascade control can improve the performance of the loop.

Assessment evidence for M1 is likely to be an extension to the assignment that covers P1, P2 and P3. Learners could be asked to design a new control loop in block diagram form to meet a given control specification. This specification can be addressed through the design and identification of control system elements whose transfer functions will contribute to an overall system transfer function. This type of activity could be supported through the use of simulation software to confirm that the specification has been met.

Assessment evidence for criterion M2 could be achieved through the assignment covering P8, P9 and P10. Learners could be asked to design a hierarchical control structure to meet a given specification, in terms of plant size and plant operation. This design may be in the form of a block diagram supported by an explanation for the choice of system and constituent elements.

Assessment evidence for criteria D1 will be an extension of M1, requiring an evaluation of the design in relation to the given specification. D2 is likely to be achieved through an extension of the assignment covering criteria P8, P9, P10 and M2. Learners could be asked to evaluate the performance of a system that is controlling a given industrial process plant. This evaluation will consider the operation and performance of the system and learners could be requested to suggest improvements to both the structure and the selection of control method.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
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<th>Scenario</th>
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<td>P1, P2, P3, M1, D1</td>
<td>Characteristics of Process Control</td>
<td>Learners need to describe the operation of a control system.</td>
<td>A written report.</td>
</tr>
<tr>
<td>P4, P5, P6, P7</td>
<td>Modes of Control</td>
<td>Learners describe the use of controllers and use tuning methods.</td>
<td>A written report and logbook from practical activities supported by witness statements</td>
</tr>
<tr>
<td>P8, P9, P10, M2, D2</td>
<td>Hierarchical and Advanced Process Control</td>
<td>Learners explain process control systems.</td>
<td>A written report.</td>
</tr>
</tbody>
</table>

Essential resources

For this unit, learners should have access to a relevant workshop or laboratory facilities, including:

- industrial plant, rigs or system simulators
- control system simulation software
- data books and manufacturers’ specifications
- process rig schematics
- appropriate tools.

Indicative reading for learners

Textbook

ISBN 9780750664325
Unit 47: Industrial Process Controllers

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Control engineering plays an important role in ensuring that process plant and machine controlled systems function correctly and with optimum performance. This unit gives learners an opportunity to gain knowledge and experience of the industrial process controllers, which are the main elements in a controlled system.

The unit starts with basic control and the comparison of common control technologies and applications. It then proceeds to examine the traditional three-term controllers that are still widely used in industry and the principles required to tune and set up these controllers.

The unit then develops the knowledge and practical skills that are essential to configure and program a programmable logic controller (PLC). Various instruction types are described and learners will be required to write programs to perform a range of control applications.

Learners will gain knowledge of fault-finding techniques and tools and will write and fault-find PLCs.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Know about control system types and their applications
2. Know about the operating principles and tuning of three-term controllers
3. Know about the types and operation of programmable logic controllers
4. Be able to write and fault-find programmable logic controller programs.
Unit content

1 **Know about control system types and their applications**
   
   *Control loops:* open-loop systems; elements of closed-loop control (controller, error, correction, process, measurement, comparator); signal-flow diagrams (transfer function, calculation of steady state error)
   
   *Control system types and applications:* sequential control, e.g. component sorting, product assembly; continuous control, e.g. flow, level, temperature, displacement, velocity; batch control, e.g. chemical mixing, bottling plant, manufacturing

2 **Know about the operating principles and tuning of three-term controllers**
   
   *Operating principles:* proportional controller (proportional band, gain, steady state error, rise time, overshoot); proportional-integral (PI) controller (Kp, integral action time, integral gain, responses); proportional-integral-derivative (PID) controller (Kp, Ki, derivative action time, responses)
   
   *Controller tuning methods:* process reaction curve, e.g. level, velocity; ultimate cycle, e.g. flow, displacement; lambda, e.g. paper mill, large holding tanks; adaptive; auto tuning

3 **Know about the types and operation of programmable logic controllers**
   
   *Programmable controller types:* unitary; modular; rack-mounted; selection to meet specification, e.g. application, cost, versatility
   
   *Operational characteristics:* central processing unit (CPU); arithmetic logic unit (ALU), flags, registers); input/output (I/O); memory organisation; scanning
   
   *System hardware and software:* specification of I/O units, e.g. digital, analogue; power supply; operating system; configuration of I/O; number systems, e.g. binary, octal, hexadecimal, binary-coded decimal (BCD)
   
   *External input and output devices:* mechanical switches; relays, e.g. electromechanical, solid state; input transducers, e.g. temperature, pressure, flow, smart sensors; output devices, e.g. motors, pumps, valves, audio or visual display

4 **Be able to write and fault-find programmable logic controller programs**
   
   *PLC programs:* program applications, e.g. on-off process control, washing machine, traffic lights, conveyor control with component sorting
   
   *PLC instructions:* ladder relay instructions; bit instructions; branches; timers; counters; logical instructions; arithmetic instructions
   
   *Test and debug programs:* software debug instructions; diagnostic indicators; data monitors; search and force facilities
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td>P1</td>
<td>describe control loops in terms of their individual elements</td>
<td></td>
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</tr>
<tr>
<td>P2</td>
<td>determine transfer functions and values for steady state error from closed-loop signal-flow diagrams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>describe the three different control system types and identify an application for each type</td>
<td>M1 explain why the control system type is suitable for the particular application</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>describe the operating principles of a three-term controller in terms of its three constituent parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>describe an appropriate tuning method for three different applications</td>
<td>M2 apply an alternative to a given tuning method so as to improve the performance of a given process controller in terms of its system response</td>
<td>D1 compare the functionality of adaptive and auto-tuning methods</td>
</tr>
<tr>
<td>P6</td>
<td>describe three types of PLC and select an appropriate type to meet a given specification</td>
<td></td>
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</tr>
<tr>
<td>P7</td>
<td>describe the four main components that identify the operating characteristics of a PLC</td>
<td></td>
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</tr>
</tbody>
</table>
## Assessment and grading criteria

<table>
<thead>
<tr>
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<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P8</strong> select system hardware and software elements that will be required to meet a given specification</td>
<td><strong>M3</strong> explain why the elements selected meet the requirements of the specification</td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> describe the four different types of external input and output devices that can be connected to a PLC for plant control or monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P10</strong> write and document a PLC program using the seven different instruction types that will control a given application</td>
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</tr>
<tr>
<td><strong>P11</strong> carry out fault-finding on a PLC program using common debugging tools.</td>
<td><strong>M4</strong> explain the methods and tools used to carry out fault-finding.</td>
<td><strong>D2</strong> analyse a given PLC control program and identify improvements that can be made to improve control system performance.</td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

Assessment evidence for pass criteria P1, P2, P3 and M1 could be produced through a written assignment. The first part of the assessment could ask learners to describe, with the aid of signal-flow diagrams, the difference between an open-loop and a closed-loop system (P1). The second part of this assessment could ask learners to calculate the overall system transfer function of a given closed-loop system (e.g. velocity control) and then calculate the steady error using the transfer function result (P2). The final part of the assessment could look at types of control systems in terms of application (P3). For example a computer-controlled washing machine could be given and learners asked to identify and describe the type of control system and the control processes that will occur. The same example could be used to develop an explanation for its suitability (M1).

Pass criteria P4 and P5 could be assessed through a written assignment, supported by practical formative tasks. This could ask learners to consider a given control system and determine and describe the operating principles of the controller using practical investigations (P4). As a second part of the assessment, learners could be given three different control systems. They could then be asked to select a tuning method for each system (P5).

Evidence for pass criteria P6–P9 could be produced through a short research project. Learners could be asked to research the types of PLC (P6), PLC operating characteristics (P7) and PLC hardware/software (P8) that would be required to meet a given specification. This specification could include information regarding system type, I/O requirement, interface, software requirements and communication system. The project report should include a description of the three types of PLC (unitary, modular and rack mounted) and identify the most appropriate for the given specification (P6).

The response for P7 should include a description of the four component parts listed in the unit content of the operational characteristics (CPU, I/O, memory organisation and scanning). The last part of the report should include the hardware and software requirements to meet the given specification (P8) and include an explanation of the suitability of the elements selected (M3).

A final task in the research project could ask learners to describe a mechanical switch, a relay, an input transducer and an output device (P9) that could be part of the selected solution for the given specification. The given specification needs to be carefully thought through before it is given to learners to ensure that all pass criteria can be evidenced.

A final assignment covering pass criteria P10 and P11 could be in the form of a practical PLC workshop. Learners could be given access to a process rig and be asked to identify the input and output devices found on the rig (e.g. sensors and motors) and connect the PLC to these devices. It is important that these devices include a mechanical switch, a relay, an input transducer and an output device as listed in the unit content. Once the PLC is connected to the rig, learners could be asked to write, document, debug and fault-find a PLC program that will provide rig control (P10 and P11). A witness statement/observation record may be the best way to record the evidence for criteria P10 and P11, supported by annotated photographs and the documented PLC program.
Assessment evidence for M2 is likely to be collected as an extension to the assignment covering criteria P4 and P5. Having selected a tuning method for three different systems, learners could be given a tuned system with an identified tuning method. They could then be asked to select and apply an alternative tuning method that will improve the original system response. The final task of this assignment would involve a comparison of adaptive and auto-tuning methods (D1).

Criterion M4 could be achieved through an extension to the assignment covering criteria P10 and P11. Having written a PLC program to meet a specification, learners could be asked to redesign the program to meet a new specification that identifies the maximum number of lines of code. This will require learners to produce an elegant program structure. The program would still be required to meet specification.

Assessment of D2 could be achieved through an extension of the assignment covering criteria P10, P11 and M4. Learners could be asked to analyse the performance of a given short PLC control program and identify improvements to the program operation in terms of operating speed and memory use. Learners could then be asked to alter the program and measure its performance against the original.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3</td>
<td>Control System Types and Applications</td>
<td>Learners to produce an information leaflet detailing control systems and their applications.</td>
<td>A written assignment.</td>
</tr>
<tr>
<td>P4, P5, M1</td>
<td>Three-Term Controllers</td>
<td>Learners to produce a report describing three-term controllers and identifying the most appropriate tuning method for different applications.</td>
<td>A written assignment.</td>
</tr>
<tr>
<td>P6, P7, P8, P9</td>
<td>Programmable Logic Controllers</td>
<td>Learners have been asked to research and produce a report on the different types of PLC.</td>
<td>A written assignment.</td>
</tr>
<tr>
<td>P10, P11, M2, D1</td>
<td>PLC Programs</td>
<td>Learners to write and fault-find a PLC program.</td>
<td>A practical assignment supported by observation records and annotated photos.</td>
</tr>
</tbody>
</table>

Essential resources

Centres will need to provide access to process controllers, process rigs, data books and manufacturers’ specifications.

Indicative reading for learners

Textbooks


Unit 48: Principles and Operation of Three-phase Systems

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

Three-phase systems are used to deliver the great amounts of power required to supply industrial, commercial and domestic demand. These systems can be divided into three main categories – generation, transmission and distribution.

This unit will cover the principles of the basic circuit configurations that are common to all parts of the electricity supply system. Circuits are connected in either star or delta using three wire circuits wherever possible, as four wire circuits are normally only used where division into single-phase distribution is required. The unit also covers the equipment required to protect systems against faults and the procedures used to operate systems safely and legally.

On completion of this unit, learners will have a broad knowledge of the design and operation of three-phase circuits. This will include being able to read and produce simple circuit diagrams, make simple measurements and knowledge of the principles of system operation and maintenance.

This unit provides a foundation for anyone interested in taking up a career in the electricity supply, manufacturing or processing industries. In large factories and processing plants, three-phase systems are used for internal distribution.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:
1. Be able to use electrical relationships and determine current, voltage and power quantities for three-phase circuits
2. Know about the operation of three-phase supply systems
3. Be able to calculate parameters and carry out measurements in three-phase balanced and unbalanced loads
4. Know how three-phase power is protected and monitored and the safety requirements for working on high voltage equipment.
Unit content

1 Be able to use electrical relationships and determine current, voltage and power quantities for three-phase circuits

*Three-phase circuit relationships:* systems of connection, e.g. 3-wire star, 4-wire star, delta; phasor diagrams

*Current and voltage:* star connection; delta connection; line and phase voltages; line and phase currents

*Power in balanced loads:* the power triangle, e.g. real, reactive and apparent power values, relationships; real power, e.g. single-phase equation, phase angle, power factor (PF); three-phase power, e.g. total power relationships from phase and line currents and voltages, calculations involving phase and total power, kW, kVAr and kVA values

2 Know about the operation of three-phase supply systems

*Three-phase supplies:* diagrammatic representation; system generation, transmission and distribution, e.g. National Grid, schematic diagrams, operating voltages (such as 400 kV, 275 kV, 132 kV, 33 kV, 11 kV, 400 V, 110 V), transformer connections (such as star-delta, star-star, delta-star)

*Principle of operation of synchronous generators (alternators):* calculations, e.g. emf, voltage, leading/lagging power factor, power, efficiency; production of three-phase emfs, e.g. distributed winding, salient pole, frequency, pole pairs, synchronous speed, phase sequence, effect of excitation; characteristics, e.g. open circuit, v-curves

*Construction of alternators:* rotor, e.g. cylindrical, salient pole; stator, e.g. distributed windings, single layer, double layer; excitation methods, e.g. DC exciter, AC exciter, brushless; parallel operation of generators, e.g. conditions for synchronising onto supply system, voltage control

3 Be able to calculate parameters and carry out measurements in three-phase balanced and unbalanced loads

*Circuits:* calculations, e.g. parameters (such as line and phase voltages, line and phase currents, real power, apparent power, reactive power, power factor, phase angles, 3- and 4-wire circuit currents, line, phase and neutral currents), phasor diagrams (such as sketches, scaled diagrams, determination of values); circuits, e.g. balanced star and delta, unbalanced star and delta

*Measurement of three-phase power:* parameters from practical measurements, e.g. voltage, current, real power, line and phase voltages, line, phase and neutral currents; measurement methods, e.g. single wattmeter for 4-wire balanced circuits, three wattmeter and two wattmeter methods for unbalanced loads; equipment for practical measurements, e.g. voltmeter, ammeter, wattmeter
4 Know how three-phase power is protected and monitored and the safety requirements for working on high voltage equipment

*Faults and protection*: protection equipment, e.g. current transformers, voltage transformers, relays; protection of three-phase generators and transformers; common faults, e.g. excess current, overvoltage, phase to phase, phase to earth; monitoring equipment, e.g. voltmeter, ammeter, wattmeter, frequency meter, PF meter, kVAR meter, kVA meter

*Supply considerations*: availability of supply, e.g. single-phase, three-phase, voltage; tariff structures, e.g. commercial, industrial, maximum demand, metering and recording arrangements, methods and connection of power factor improvement equipment (such as capacity banks, capacitors on individual machines, synchronous motors operating on leading PF)

*Safety*: safety precautions when working, e.g. warning notices, labelling, working space, earthing arrangements, interlocking arrangements, personal protective equipment, rubber mats, barriers, insulated tools, test equipment; documentation, e.g. limitation of access, permit to work, sanction for test

*Equipment, machines and systems*: equipment, e.g. switchgear, protection apparatus, monitoring apparatus; machines e.g. generators, transformers; systems, e.g. transmission networks, distribution networks
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<td><strong>P1</strong> demonstrate current and voltage quantities for star and delta connections using three-phase circuit relationships</td>
<td><strong>M1</strong> explain the operation of the protection system on a three-phase transmission line in the event of a given common fault</td>
<td><strong>D1</strong> explain, using numerical examples, the need for different voltages for different parts of the generation, transmission and distribution systems</td>
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</tr>
<tr>
<td><strong>P2</strong> determine real power and three-phase power for both star and delta connections, including the use of the power triangle</td>
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</tr>
<tr>
<td><strong>P3</strong> describe the system of three-phase generation, transmission and distribution</td>
<td><strong>M2</strong> using practical examples and/or characteristics, explain how the variation of excitation of an alternator can be used to control power factor</td>
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<tr>
<td><strong>P4</strong> describe the principle of operation of a synchronous generator (alternator) with the aid of calculations</td>
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<tr>
<td><strong>P5</strong> describe the function of the components in an alternator</td>
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<tr>
<td><strong>P6</strong> carry out calculations relating to line and phase voltages and currents in circuits with balanced and unbalanced three-phase loads</td>
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Assessment and grading criteria

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<tr>
<td><strong>P7</strong> measure voltages, currents and real power in circuits with balanced and unbalanced three-phase loads</td>
<td><strong>M3</strong> explain why it is important to use the correct equipment when measuring three-phase power and the impact this would have on circuit calculations when using any of these measurements</td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> describe the equipment required to protect three-phase generators and transformers against common faults and the equipment required to monitor supplies</td>
<td><strong>M4</strong> explain the different tariff structures and how this could lead to the connection of power factor improvement equipment.</td>
<td><strong>D2</strong> evaluate the benefits to commercial consumers and suppliers of installing power factor improvement equipment on consumers’ equipment.</td>
</tr>
<tr>
<td><strong>P9</strong> describe the equipment and documentation required for safe working on high voltage equipment, machines and systems.</td>
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</tbody>
</table>
Essential guidance for tutors

Assessment

The unit could be assessed using three assignments. The first assignment could be based on circuits throughout the supply system and the reasons for the choice of voltages. This could cover criteria P1, P2, P3, M1 and D1 and ensure diagrams are suitably detailed. Exercises on numerical and phase relationships could be used to achieve P1 and P2. It is important that both line and phase voltages and currents are covered. To ensure authenticity of evidence, data would need to be varied for each learner. Alternatively the tasks for P1 and P2 could be carried out first in a time-controlled environment and then the rest of the assignment carried out in learners’ own time.

To achieve P3, diagrams of parts of the supply system for P3 could be coupled with explanations of the reasons for choosing different voltages at D1. At distinction level, such an exercise would require numerical evidence to be analysed to support the principles applied in selecting a voltage. Realistic or measured values should be used at all times. The assignment could be completed with a task to explain the protection system (M1).

The second assignment could cover the major aspects of power in three-phase systems and enable achievement of criteria P4, P5, P6 and M2.

The generation of power and the control of all types of power and power factor throughout the system are the main features of this assignment to ensure the understanding of each component and their purpose. Results from practical tests could be used for part or all of the work, although in this assignment the practical element is not being assessed. Simulation packages and low voltage equipment could be used for the measurements if other methods are not available.

As with the first assignment, data could be varied for each learner or these tasks could be carried out first in a time-controlled environment to ensure authenticity. As well as the requirement for carrying out calculations, the task to achieve P4 should consider the production of three-phase emfs and characteristics.

A written task could then be given asking learners to describe the function of an alternator and in doing so should include rotor, stator and excitation aspects, as well as parallel operation of generators.

A further task could be given to achieve M2. The tasks for P4 and P6 could be done under controlled conditions and P5 and M2 by the learner in their own time, clearly evidencing the components that make up an alternator.

The third assignment could focus on the protection of the system and the techniques of making work on high voltage systems safe. This would cover criteria P7, P8, P9, M3, M4 and D2.

To demonstrate an appreciation of the whole system, learners would need to explain how and why it is important to operate at an economical power factor (D2). The consumer’s equipment would be found at the user end of the transmission and distribution networks. For this assignment, a visit to a power station, sub-station or large industrial plant could provide the required background information.

A practical task needs to be set to measure voltages, current and real power (P7), and in the task there should be scope to cover measurement methods and equipment requirements. The evidence for this criterion is likely to be in the form of a witness statement/observation record supplemented by a table of results and annotated photographs.
A written task is required for P8 and P9 and further written tasks for M3 and M4. The task for P9 should ensure that equipment and documentation requirements are considered when working on all three aspects of high voltage. These should include a type of equipment, a type of machine and a type of system as listed in the content section of learning outcome 4.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<th>Scenario</th>
<th>Assessment method</th>
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<tbody>
<tr>
<td>P1, P2, P3, M1, D1</td>
<td>Three-Phase Circuits</td>
<td>A technician has been asked to look at a range of circuits in the supply system and determine current, voltage and power quantities.</td>
<td>A controlled test to determine current, voltage and power quantities, plus a written explanation/diagrams of three-phase generation, transmission and distribution, including reasons for choice of different voltages.</td>
</tr>
<tr>
<td>P4, P5, P6, M2</td>
<td>Power Generation and Control</td>
<td>A technician needs to determine the operation of three-phase supply systems and line and phase voltages and currents.</td>
<td>A controlled test to determine operation of a synchronous generator line and phase voltages and currents, plus a written description of an alternator.</td>
</tr>
<tr>
<td>P7, P8, P9, M3, M4, D2</td>
<td>Protection and Safety Requirements for Three-Phase Power</td>
<td>A technician must show a new learner how to measure voltages, current and real power and explain the use of relevant protection and safety equipment.</td>
<td>Results from practical measurement tasks supported by observation records, plus a written report.</td>
</tr>
</tbody>
</table>
Essential resources

Centres delivering this unit must have access to industrial standard three-phase equipment and systems. Appropriate and adequate testing instruments and measurement equipment should also be provided.

A range of relevant international and British Standards and health and safety publications should be available.

Indicative reading for learners

Textbooks


Bird J – *Electrical and Electronic Principles and Technology* (Routledge, 2013) ISBN 9780415662857
Unit 49: Industrial Robot Technology

Level: 3  
Unit type: Optional  
Assessment type: Internal  
Guided learning: 60

Unit introduction

This unit will give learners an understanding of the principles and operation of industrial robots used in modern manufacturing. The unit will cover robot control systems, the operating principles of different types of sensors used and their application in an industrial robot.

Learners will gain an understanding of the programming methods used and will be required to produce a working program for an industrial robot or robot work cell. The unit will give learners an understanding of the health and safety and maintenance requirements associated with modern industrial robots.

Note that the use of ‘e.g.’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘e.g.’ needs to be taught or assessed.

Learning outcomes

On completion of this unit a learner should:

1. Understand the operating, design and control principles of modern industrial robots and typical robot work cells
2. Understand the operating principles of industrial robot sensors and end effectors
3. Be able to produce a working program for an industrial robot or robot work cell
4. Know the hazards and health, safety and maintenance requirements associated with industrial robots and robot work cells.
Unit content

1 Understand the operating, design and control principles of modern industrial robots and robot work cells

*Principles of operation:* operational characteristics and specifications; types of controller, manipulator, end effector/tooling, e.g. pneumatic suction cup, hydraulic, electrical and mechanical grippers; work space organisation, e.g. feed of work, robot-to-robot work, material flow and logistics

*Design principles:* manipulator coordinate systems, e.g. cylindrical spherical, jointed, spherical, Selective Compliance Assembly Robot Arm (SCARA) with associated working envelope; wrist articulations, e.g. yaw, pitch and roll, degrees of freedom in terms of translations and rotations; drive mechanisms: mechanical (ball screws, chain/belt, gears), pneumatic, hydraulic, electrical; speed reducers/gearheads, e.g. harmonic, cycloidal, parallel shaft spur gear, planetary

*Control systems:* on/off and proportional-integral-derivative (PID) control; closed-loop servo controlled systems e.g. for driving one axis of a robot; input, output and feedback signals e.g. the sequence which takes place in order to perform a task; control of three axes of a robot

2 Understand the operating principles of industrial robot sensors and end effectors

*Sensors:* sensor types, e.g. tactile (micro switches/piezoelectric/strain gauge/pressure), non-tactile (capacitive/inductive/light/laser), vision (inspection, identification and navigation); sensor applications, e.g. safety, work-cell control, component/part inspection

*End effectors:* grippers and tools, e.g. parts handling/transfer, assembly, welding, paint spraying, testing

3 Be able to produce a working program for an industrial robot or robot work cell

*Operating program:* program selection, start-up, test, alterations and operation; types of programming, e.g. manual, walk through, teach pendant methods; off-line programming; planning robot efficient routes; writing programs using flowcharts; work-cell commands, e.g. wait/signal/delay

4 Know the hazards and health, safety and maintenance requirements associated with industrial robots and robot work cells

*Health and safety requirements:* relevant regulations, e.g. Health and Safety at Work etc. Act 1974, Electricity at Work Regulations 1989, Health and Safety Executive (HSE) publications; human dangers, e.g. during programming, maintenance and as a result of system faults; safety barriers, e.g. 'dead man's handle', hold and emergency stop buttons, pressure pads/matting surrounding robot, infrared curtains and electromagnetic field barriers

*Maintenance:* inspection routines, e.g. mechanical condition of all parts, environmental conditions (particulate matter, temperature, ventilation, shock, vibration, electrical noise); spare parts required to sustain continuous operation; relevant maintenance tools and test equipment; set-up and maintenance schedules
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<td><strong>P1</strong></td>
<td>explain the operating principles of a given industrial robot or robot work cell</td>
<td><strong>M1</strong> explain how the design principles of a given industrial robot or robot work cell are reflected in its control and operation</td>
<td><strong>D1</strong> evaluate an industrial robot or robot work cell installation in terms of its design, operation and control</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>explain the design principles of a given industrial robot or robot work cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>describe the control systems, including input, output and feedback signals, used to control the operation of an industrial robot or robot work cell to perform a specific task</td>
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</tr>
<tr>
<td><strong>P4</strong></td>
<td>explain the operating principles of three different types of sensors and their relevant application in an industrial robot or robot work cell</td>
<td><strong>M2</strong> justify the use of a specific sensor/end effector for a given industrial robot or robot work cell application</td>
<td></td>
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<tr>
<td><strong>P5</strong></td>
<td>explain the relevant operating principles of two different industrial robot or robot work cell end effectors being used to perform a specific task</td>
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</tr>
<tr>
<td>Assessment and grading criteria</td>
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<td></td>
</tr>
<tr>
<td><strong>P6</strong> produce an operating program for an industrial robot or robot work cell to enable it to effectively carry out a specific function</td>
<td><strong>M3</strong> test that an industrial robot or robot work cell conforms to a specification and performs the programmed tasks correctly and safely</td>
<td><strong>D2</strong> compare two different methods used to program an industrial robot or robot work cell for a specific operation, and justify the choice of one over the other.</td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> describe the health and safety requirements for the safe operation of a given industrial robot or robot work cell</td>
<td><strong>M4</strong> justify the choice of a safety barrier for a given industrial robot or robot work cell operation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> describe maintenance procedures on a given industrial robot or robot work cell.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

One assignment could cover P1, P2, P3, M1 and D1. For P1, learners will need to explain the principles of operation of robots, including types of controller, manipulator, end effector/tooler and work space organisation. This can be linked to P2 so that their explanation also includes robot design principles (manipulator coordinate systems, wrist articulations, drive mechanisms and speed reducers). Learners will need to describe types and applications of control systems suitable for robots (P3). A separate task could be used to combine M1 and D1, which essentially synthesises P1, P2 and P3 and requires an evaluation of a given industrial robot or robot work cell in terms of its design, operation and control.

A second assignment could cover P4, P5 and M2. For P4, learners will need to explain the operation of three different sensors and their different applications. This can be linked to P5 where they will need to provide details of robot end effectors. M2 combines P4 and P5. Learners could select one example used in P4 to justify sensor use and one example from P5 for end effector use or use one example to combine the two.

A third assignment could be used to cover P6, M3 and D2. For P6, a robot must be programmed and the program produced should be tested in order to achieve M3. It is suggested that the program should be centred on industrially relevant tasks. The ability to have used two programming methods and subsequently to evaluate and compare them is also necessary to achieve D2.

A fourth assignment could be used to cover P7, P8 and M4. A clear awareness of health and safety (P7) and maintenance issues (P8) associated with robots should be shown through the assessment tasks. To achieve M4, learners must be aware of safety and choose and justify the choice of a safety barrier in an industrially relevant situation.

Learners must select and interpret from a range of sources of information, such as manufacturers' literature, textbooks and the internet. Learners should require significantly less tutor help or guidance when carrying out assessable practical activities.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, M1, D1</td>
<td>Robot Operation, Design and Control Principles</td>
<td>A technician needs to evaluate the operation, design and control of a robot to see if improvements can be made.</td>
<td>A written report.</td>
</tr>
<tr>
<td>P4, P5, M2</td>
<td>Sensors and End Effectors</td>
<td>A technician needs to explain to a new learner the operating principles of robot sensors and end effectors.</td>
<td>A written report.</td>
</tr>
<tr>
<td>P6, M3, D2</td>
<td>Producing and Testing Operating Programs for Industrial Robots</td>
<td>A technician needs to produce and test an operating program for an industrial robot.</td>
<td>A practical task supported by learners' written records and records of tutor observation.</td>
</tr>
<tr>
<td>P7, P8, M4</td>
<td>Health, Safety and Maintenance With Industrial Robots</td>
<td>A health and safety manager requires a report on health and safety requirements for an industrial robot, along with maintenance procedures.</td>
<td>A written report.</td>
</tr>
</tbody>
</table>
Essential resources

Centres delivering this unit should be equipped with, or have access to, an industrial standard robot or smaller educational-standard robots. Learners are expected to undertake programming exercises and be encouraged to set up robot controlled systems/processes.

Indicative reading for learners

Textbooks


Unit 50: Helicopter Aerodynamics and Flight Principles

Level: 3
Unit type: Mandatory
Assessment type: Internal
Guided learning: 60

Unit introduction

The usefulness of a helicopter lies in its ability to take off and land vertically on almost any terrain, to hover stationary relative to the ground, and to fly forward, backward or sideways. These unique flying characteristics, however, come at a price, including complex aerodynamic problems and relatively large power requirements compared to fixed wing aircraft of the same weight.

In this unit, learners will gain an understanding of the atmosphere in which aircraft of all types fly and the mechanical and fluid principles associated with their flight. They will explore, through practical experimentation, the effects of airflow over aerodynamic surfaces, as well as how lift and drag are generated and how they interact during flight. Finally, learners will gain an understanding of the principles of helicopter flight and how helicopter control is obtained.

If learners want to work in the rotary wing aircraft industry then understanding how lift is achieved and how helicopters are controlled is essential. Studying this unit will help them progress to aircraft engineering technician roles in rotary wing aircraft manufacture, maintenance, component overhaul and repair. It will also help learners progress to higher education to study aerodynamics or flight mechanics or, alternatively, assist with gaining entry to other aeronautical engineering degrees.

Learning outcomes

On completion of this unit a learner should:
1. Examine the atmospheric, mechanical and fluid principles affecting flight
2. Explore safely the lift and drag force generation and interaction that create aircraft flight
3. Explore helicopter flight principles and how control of a helicopter is obtained.
Unit content

1 Examine the atmospheric, mechanical and fluid principles affecting flight

The atmosphere, the International Standard Atmosphere (ISA) and its effect on flight

- The atmosphere:
  - composition of the air in the Earth’s atmosphere
  - layers of the Earth’s atmosphere to include the troposphere, stratosphere, mesosphere, thermosphere and exosphere
  - changes to the atmospheric air pressure, density and temperature
  - danger to flight due to severe atmospheric events, including:
    - lightning strike and the methods used to mitigate the effects
    - severe air turbulence and the possible effects on the aircraft
    - bird strike, hail strike
    - frost and ice accretion and their effects on aerodynamic performance.

- The International Standard Atmosphere (ISA):
  - the need for and functions of the ISA
  - define pressure (barometric, atmospheric, absolute), temperature (Kelvin, Centigrade, Fahrenheit, absolute), density, density ratio, dynamic viscosity, kinematic viscosity and sonic velocity
  - significance of and numerical values for the tropopause, temperature lapse rate, the temperature in the stratosphere
  - standard ISA values for the properties of air at ground level and their changes with altitude, to include pressure ($P$), density ($\rho$), temperature ($T$) dynamic (absolute) viscosity ($\mu$), kinematic viscosity ($v$) sonic velocity ($a$)
  - define the characteristic gas constant ($R$), the specific heat capacity of a gas at constant volume ($C_v$) and constant pressure ($C_p$), the ratio of specific heats $\gamma = \frac{C_p}{C_v}$
  - numerical values of $R$, $C_v$, $C_p$ and $\gamma$, for air, under standard conditions
  - the use of the ideal gas laws and characteristic gas equation in mass form $pv = mRT$ to solve numerical problems on the density, pressure, mass and temperature of air, under differing conditions
  - the use of ISA tables to find changes in pressure, density, absolute viscosity, kinematic viscosity and sonic velocity, for varying altitudes
  - the density ratio ($\sigma$), and its relationship to the equivalent airspeed (EAS) and true airspeed (TAS) at varying altitudes
  - the use of the temperature lapse rate equation ($T = T_0 - Lh$), the sonic velocity approximation $a = \sqrt{\frac{RT}{\gamma}} = 20.05\sqrt{T}$ and the density ratio, to determine properties of air at varying altitudes.
Fluid flow and mechanical principles

- Newton’s laws, including:
  - second law and its relationship to forces generated by aircraft acceleration
  - third law and its relationship to flight forces and to the generation of aircraft lift.

- Continuity equation for laminar constant incompressible steady flow, volume flow rate given by $Q = A_1v_1 + A_2v_2$ and for unsteady variable density flow, the mass flow rate is given by $\dot{M} = \rho_1A_1v_1 = \rho_2A_2v_2$

- The Venturi principle and the nature of flow through a Venturi tube.

- The Bernoulli equation for incompressible steady flow:
  $$\rho gh_1 + \frac{1}{2} \rho v_1^2 + p_1 = \rho gh_2 + \frac{1}{2} \rho v_2^2 + p_2$$
  also for total energy in a steady stream $\rho + \frac{1}{2} \rho v^2 = c$

- Centripetal and centrifugal accelerations where $a = \frac{v^2}{r}$ and resulting forces where $F = \frac{mv^2}{r}$

- Couples and turning moments where torque $T = F \times r$

- Principle of moments and balancing forces.

- Pressure measurement (mercury and aneroid barometer, manometer).

Application of mechanical principles to aircraft flight

- Flight forces:
  - position and equality of lift, weight, thrust and drag forces for straight and level flight
  - flight force couples (lift/weight and thrust/drag), action about centre of gravity (CG) and centre of pressure (CP)
  - balancing aerodynamic force from tailplane
  - using the principle of moments, determine balancing forces needed to maintain aircraft in static equilibrium.

- Flight forces in steady manoeuvres:
  - diagrammatic arrangement for system of forces and their components during gliding flight, diving flight, climbing flight and turning flight where
    $$L\sin\theta = \frac{mv^2}{r} \text{ and } \tan\theta = \frac{v^2}{gr}$$
  - the definition and significance of load factors
  - analytical solution of flight force parameters, during flight manoeuvres
  - the effects of excessive manoeuvre loads on airframe structure, including pulled rivets, skin buckling, fuel and oil leakage, visual structural cracking, asymmetry of structure
  - methods used to prevent the loss of aircraft structural integrity in the event of overstressing damage, including: failsafe, safe life and on-condition structure, redundancy, radiation shields, planned maintenance, maintenance frequency
o post-flight checks after flight through severe atmospheric events, including: examination of aircraft structure for damage, symmetry, examination for lightning and high intensity radiation field (HIRF) damage, instrument damage and degaussing, controls freedom of movement.

2 Explore safely the lift and drag force generation and interaction that create aircraft flight

The nature and effects of subsonic airflow over aerofoil sections

- The nature of subsonic airflow, including streamline, laminar and turbulent flow, compressibility effects at higher subsonic speeds.
- Aerofoil terminology, including aerofoil profile, camber, upper, lower and mean camber lines, chord line, leading and trailing edge, thickness/chord ratio or fineness ratio, angle of attack (AOA), angle of incidence (AOI).
- Viscosity effects and the boundary layer, including resistance to motion, velocity gradient, shear rate, boundary layer separation (transition point, separation point).
- Flow over aerofoil sections, including free stream, laminar and turbulent flow, relative airflow, up and down wash, stagnation point, separation.
- Pressure and flow changes at low, medium and high angles of attack and aerofoil stall effects.
- Airflow and aerodynamic shape, including aerofoils (flow over thin, medium, thick and symmetrical aerofoil sections), wings (aspect ratio, generation of tip vortices).

Aircraft lift, drag and their interaction

- Lift:
  - factors affecting lift, including aerofoil shape, lift coefficient, angle of attack, air density, airspeed and stall
  - centre of pressure and lift force
  - parameters and use of the lift equation, \( L = C_L \frac{1}{2} \rho v^2 S \)
  - wing plan form designs for aircraft subject to low subsonic, high subsonic and transonic speed airflows
  - Effects that wing plan forms have on the generation of lift
  - use and types of wind tunnel apparatus, e.g. air blowers, lift and drag balances, open and closed section tunnels, flow visualisation equipment, airflow pressure and speed-measuring devices, aerofoil sections and whole aircraft models
  - measurement of lift forces using wind-tunnel apparatus
  - significance and interpretation of pressure plots for varying angles of attack and airspeed.
• Drag:
  o types of drag, including total, induced (trailing vortex), profile skin friction, profile form, interference
  o factors affecting drag, including aerofoil shape, angle of attack, drag coefficient, airspeed, streamlining, damage to lift producing surfaces, ice and frost accretion
  o drag reduction methods, including polished surfaces, fairings
  o parameters and use of the drag equation \( D = C_D \frac{1}{2} \rho v^2 S \)
  o significance and interpretation of profile, induced and total drag plots versus airspeed
  o measurement of drag forces using wind tunnel apparatus
  o theoretical determination of drag forces.

• Lift and drag interaction:
  o significance and interpretation of lift and drag plots
  o polar plots of lift coefficient against drag coefficient and their interpretation
  o plots of profile drag and induced drag (total drag) against airspeed
  o minimum drag, the lift/drag ratio and aerofoil efficiency
  o optimum angle of incidence (AOI).

• Interpretation of aircraft model wind tunnel test results for lift, drag and pitching moment.

3 Explore helicopter flight principles and how control of a helicopter is obtained

Helicopter flight principles
• modes of flight (vertical, lateral, fore and aft, hover, spot turns)
• coning angle, Coriolis effect, translational lift, dissymmetry of lift, gyroscopic precession
• autorotation, vortex ring state

Helicopter control
• main rotor disc
• collective and cyclic controls
• tail rotor
• yaw control
• main rotor head control:
  o swash plate, spider arm
  o effect of control movement.
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<tr>
<td><strong>P1</strong></td>
<td>calculate the atmospheric changes due to varying altitudes and conditions, explaining the effects of these changes on aircraft flight</td>
<td><strong>M1</strong> analyse the dangers to flight caused by altitude and severe atmospheric events, identifying the nature of possible damage and appropriate mitigation methods</td>
<td><strong>D1</strong> evaluate, using language that is technically correct and of a high standard, how the structural design of an aircraft mitigates the impact of excessive flight forces and how post flight checks identify defects</td>
</tr>
<tr>
<td><strong>P2</strong></td>
<td>explain the mechanical and fluid principles that enable flight</td>
<td><strong>M2</strong> analyse the forces that result from aircraft flight, identifying the nature of structural damage that may occur from the aircraft being subject to excessive loading</td>
<td></td>
</tr>
<tr>
<td><strong>P3</strong></td>
<td>explain the nature of the loads and loading parameters imposed on the airframe during flight manoeuvres</td>
<td><strong>M3</strong> conduct experiments accurately to determine the lift and drag forces produced from variable state and variable speed air flowing over different aerofoil sections set at three angles of attack</td>
<td></td>
</tr>
<tr>
<td><strong>P4</strong></td>
<td>conduct experiments safely to determine the lift and drag forces produced from steady state air at two different speeds flowing over two different aerofoil sections set at three angles of attack</td>
<td><strong>M4</strong> conduct experiments accurately to determine the lift and drag forces produced from variable state and variable speed air flowing over different aerofoil sections set at three angles of attack</td>
<td></td>
</tr>
<tr>
<td><strong>D2</strong></td>
<td>evaluate the lift and drag forces and lift/drag ratios produced from variable state, variable speed air flowing over aerofoil sections under three angles of attack, comparing the results from safely conducted experiments and theoretical calculations</td>
<td></td>
<td></td>
</tr>
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## Assessment and grading criteria

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<td><strong>P5</strong> explain, using theoretical calculations and experimental results, the lift and drag forces produced from steady state air at two different speeds flowing over two different aerofoil sections set at three angles of attack</td>
<td><strong>M4</strong> analyse, using theoretical calculations and experimental results, the lift and drag forces and lift/drag ratios produced from variable state, variable speed air flowing over different aerofoil sections set at three angles of attack</td>
<td></td>
</tr>
<tr>
<td><strong>P6</strong> describe the modes of flight that are possible in a helicopter</td>
<td><strong>M5</strong> explain how main rotors are arranged on different types of helicopter to compensate for gyroscopic precession</td>
<td><strong>D3</strong> evaluate, using technically correct language, how translating tendency, Coriolis effect and dissymmetry of lift are controlled in different types of helicopter</td>
</tr>
<tr>
<td><strong>P7</strong> explain the purpose of the three helicopter flight controls and how they affect their respective rotor blades</td>
<td></td>
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</tr>
</tbody>
</table>
Essential guidance for tutors

Assessment

For P1, learners will include in their evidence a series of calculations to determine the properties of atmospheric air at differing altitudes. For P2 and P3, explanations may be limited to the more obvious changes that occur with altitude, such as the drop in temperature, pressure and density of the air in the troposphere and their effect on lift forces. Learners’ explanations should connect these changes with one or two of the more obvious atmospheric events. For example, how a drop in temperature and precipitation conditions increases the risk of frost/ice accretion and the effects this may have on aerodynamic performance and controls handling.

Evidence should demonstrate the relationship between the Venturi principle, Bernoulli’s theorem, Newton’s second law and the generation of aircraft lift forces. Aerodynamic forces that occur during aircraft manoeuvres, including gliding, climbing, pulling out from a dive and turning flight, should be explained using vector diagrams.

Overall, the explanations should be logically structured, although basic in parts, and they may contain minor technical inaccuracies relating to engineering terminology, such as confusing dynamic viscosity with kinematic viscosity or using the term ‘transition point’, when they are really talking about the separation point. Also, the calculations may contain some minor arithmetic errors.

For P4 and P5, learners will safely and correctly set up and carry out a series of experiments and obtain results. A minimum of two experiments, each with a different aerofoil section, will be used to determine the effects on lift and drag across them at low, medium and high angles of attack. There may be some minor inaccuracies in the recording of the results, estimating lift and drag forces, and relating to the engineering terminology used.

Overall, learners’ explanations will be logically structured and clearly identify the changes to airflow over the aerofoil sections at different angles of attack up to the stall, explicitly commenting on their effect on lift and drag. The explanation of each experiment will include scale diagrams that are annotated with relevant figures, for example lift and drag forces. Theoretical calculations will also be included, but there may be minor numerical and diagrammatic errors.

For P6 and P7, learners will be able to describe all modes of helicopter flight and the flight controls the pilot must operate to achieve each mode of flight. Learners will also be able to explain the purpose of each of the three helicopter flight controls and the effect each flight control has on their respective rotor blades.

Overall, the explanations should be logically structured, although basic in parts, and they may contain minor technical inaccuracies relating to engineering terminology.

For M1 and M2, learners will provide evidence for each severe atmospheric condition of one area of damage that has been identified and the corresponding mitigation methods considered.

The quantitative analysis of forces that occur during all phases of flight should include taxiing, climbing, cruising, turning and diving manoeuvres. There should be clear evidence presented that identifies the nature, and considers the likely cause of, the structural damage that may occur from excessive loading during all phases of flight.

Overall, the analysis should be logically structured, technically accurate and easy to understand.
For M3 and M4, learners will conduct accurate experimental work, to include setting up the measuring equipment and recording results methodically. The practical work will also involve running the experiments under different airflow conditions, for example to conduct the experiments under steady streamlined and unsteady/turbulent airflows.

Overall, the analysis will be logically structured, technically accurate and easy to understand. Theoretical calculations of lift and drag forces and lift/drag ratios must be accurate and conform to accepted conventions.

For M5, learners will explain how the rotors are arranged on different types of helicopter. For example, learners will explain the rotor arrangement on helicopters with two blades, four blades and five blades. The evidence produced will detail how lift and drag vary as a helicopter blade varies its angle of attack through its circular flight path and how gyroscopic precession is used to control flight due to these changes in lift and drag.

Overall, the analysis should be logically structured, technically accurate and easy to understand.

For D1, learners will produce evidence that includes a balanced evaluation of the structural design features and post-flight procedures used to ensure continuing airworthiness, including those problems presented by structural degradation. The evidence will include an accurate analysis of the aerodynamic forces acting on the aircraft during all phases of flight, as well as the dangers and atmospheric effects on flight through extreme weather events and their combined adverse effect on the aircraft during flight. In addition, there will be an evaluation of the structural design methods used to mitigate adverse effects and the post-flight procedures used to identify the defects resulting from adverse conditions.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer. For example, the evidence will be logically structured, use the correct technical engineering terms and will contain high quality written language, for example it will be grammatically clear.

For D2, learners will produce a balanced evaluation of at least two experiments undertaken with two different aerofoil sections and under different conditions, for example angles of attack. There should also be theoretical calculation of lift and drag forces and lift/drag ratios based on the airflow over at least two aerofoil sections.

The evaluation should include a comparison of the results obtained through safe experimentation and theoretical calculations, and explain why the variations occur, for example from experimental error and also from the limitations of the theoretical equations and the aerodynamic effects of wind tunnel testing when compared with real aircraft flight. Also, for example, there are the limitations with Bernoulli’s theorem, when used experimentally with both steady streamlined and unsteady/turbulent airflows.

Overall, the experimental evidence, for example a report, should be logically structured, use the correct technical engineering terms and will contain high-quality written language, for example they will be grammatically clear.

For D3, learners will evaluate how the aerodynamic problems associated with helicopter flight are controlled by design in different types of helicopter.

Overall, the evidence produced will be easy to read and understand by a third party who may or may not be an engineer. For example, the evidence will be logically structured, use the correct technical engineering terms and will contain high quality written language, for example it will be grammatically clear.
### Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

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<th>Scenario</th>
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<tbody>
<tr>
<td>P1, P2, P3, M1, M2, D1</td>
<td>Atmospheric Events and Mechanical and Fluid Principles Affecting Flight</td>
<td>An activity requiring learners to research the atmospheric events and mechanical and fluid principles that affect flight.</td>
<td>A report covering the atmosphere, the analysis of atmospheric parameters, mechanical and fluid principles and their effect on flight and continuing airworthiness.</td>
</tr>
<tr>
<td>P4, P5, M3, M4, D2</td>
<td>Lift and Drag Force Generation and Interaction</td>
<td>A series of experiments into lift and drag forces, with supporting documentation.</td>
<td>A portfolio of results gathered by experimentation when investigating airflow over aerofoil surfaces, and lift and drag generation and interaction. Supported by images, observation records, graphs and mathematical analysis.</td>
</tr>
<tr>
<td>P6, P7, M5, D3</td>
<td>Helicopter Flight and Control</td>
<td>An activity requiring learners to research helicopter flight control methods and the aerodynamic effects relating to rotary wing flight.</td>
<td>A technical report covering the modes of helicopter flight, gyroscopic precession, translating tendency, Coriolis effect, dissymmetry of lift and how rotor blades are arranged to allow flight to be controlled.</td>
</tr>
</tbody>
</table>
Essential resources

For this unit, learners must have access to:

- mechanical laboratory equipment, such as centripetal acceleration/force apparatus, Venturi and Bernoulli apparatus, Newton's cradle/Newtonian demonstrator, or similar apparatus to verify these principles
- flow visualisation apparatus, such as a smoke tunnel or a wind tunnel and prepared aerofoil sections with streamers
- an open- or closed-section wind tunnel, with lift and drag measurement equipment, speed and pressure measurement equipment. Please note that wind tunnels with manometers would be more suitable for experimental work than those with digital read-out equipment
- standard aerofoil sections, such as NACA 12 and others with known geometric parameters and pressure measurement plumbing
- workshop barometer and thermometer or other pressure and temperature measurement equipment
- actual helicopter airframes, control systems, main rotor heads and tail rotors.
Unit 51: Helicopter Gas Turbine Engines, Transmission, Rotors and Structures

Level: 3
Unit type: Optional
Assessment type: Internal
Guided learning: 60

Unit introduction

This unit will broaden learners’ knowledge and understanding of helicopter engines and transmission systems and how single rotor and twin rotor systems interact for control and stability during flight. Learners will look at the construction of a turbo-shaft engine and the systems used to monitor its performance. They will analyse the component parts and arrangement of a helicopter power train, before looking at methods used to assemble and align helicopter structures. This unit will not only be of benefit to learners studying at BTEC National level, but also those following a modern apprenticeship in helicopter manufacture or maintenance, as well as those undergoing aircraft training with the armed forces.

Learning outcomes

On completion of this unit a learner should:

1. Know the principles and construction of a helicopter turbo-shaft engine
2. Understand the principles and construction of helicopter main and tail rotor transmission systems
3. Know about helicopter structures and their assembly methods and alignment techniques
4. Know about the function and construction of helicopter flight control systems.
Unit content

1 Know the principles and construction of a helicopter turbo-shaft engine

Arrangement and operation: constructional arrangement and operation of the turbo-shaft engine, mechanical engine control, electronic engine control and fuel metering systems (FADEC)

Engine monitoring systems: eg exhaust gas temperature (EGT), turbine temperature, engine speeds (N1, N2, Ng, Nf), oil pressure, oil temperature, fuel pressure (temperature and flow), engine oil system, engine fuel system

Principles: eg potential energy, kinetic energy, Newton’s law of motion, Brayton cycle; compare relationships eg force, work, power, energy, velocity, acceleration

Modules of a turbo-shaft engine: inlet eg compressor inlet ducts, effects of various inlet configurations, ice protection; compressors eg axial, centrifugal and mixed, constructional features, operating principles, applications, fan balancing; causes and effects of compressor stall and surge; methods of air flow control eg bleed valves/bands, variable inlet guide vanes, variable stator blades; combustion section eg constructional features, principle of operation; turbine section eg operation and characteristics of different turbine blade types, disc attachment, nozzle guide vanes, causes and effects of turbine blade stress and creep; exhausts eg constructional features and principles of operation; free power turbine and main engine output shaft and gearbox arrangement and principle of operation

2 Understand the principles and construction of helicopter main and tail rotor transmission systems

Rotor operation: types of main rotor head (rigid, semi-rigid, fully articulated); gearboxes; main rotor; intermediate/angle; tail rotor; transmission systems; clutches; free wheel units (such as ramp and roller and spragg); rotor brake drive shafts (such as main engine output, intermediate and tail rotor drive)

Components: used to obtain main and tail rotor drive eg ancillary equipment (tail rotor hub, gimbal ring/ carden ring, flexible couplings), systems for fold and spread of main rotor, systems for tail pylon fold, ACSRs, bearings (radial, axial), seals (static, dynamic), lubrication types and applications

3 Know about helicopter structures and their assembly methods and alignment techniques

Helicopter structures: structures eg monocoque, semi-monocoque, truss; constructional features eg ties, struts, stringers, longerons, frames, formers, bulkheads, sub division of airframe; classification of structure eg primary, secondary, tertiary

Assembly: assembly methods eg types of fasteners, jigs and fixtures, airframe rigging, symmetry checks; alignment techniques
4 Know about the function and construction of helicopter flight control systems

*Function of flight control systems:* cyclic control eg rigging, operation, swashplate; collective control eg rigging, operation; yaw control eg anti-torque, tail rotor, NOTAR technology, bleed air, main rotor heads achieving control eg features (such as design, operational), blade dampers (such as function, construction), rotor blades (such as construction, attachment), tail rotor blades (such as construction, attachment), trim control (such as fixed stabilisers, adjustable stabilisers), system operation (such as manual, hydraulic, electrical, fly by wire)

*Construction of flight control systems:* components eg cables and pulleys, turnbuckles, brackets, levers, linkages, pivots, valves, micro-switches, locks, connecting rods, stops, jacks, dampers, yaw pedals, cyclic pitch lever, collective pitch lever, auto pilot systems, AFCS, series and parallel actuators, mixer units; types of controls and respective axes about which they provide control; collective, cyclic, yaw pedals, flying control components eg push pull tubes, torque tubes, bell cranks, gradient unit, control boosts
Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

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<td>P1</td>
<td>describe the constructional arrangement and operation of a turbo-shaft engine</td>
<td>M1 explain the working cycle of a turbo-shaft engine and identify the various modules, including the axial and centrifugal compressor and the reason for including a free power turbine</td>
<td>D1 analyse two different helicopter transmission systems used to drive both the main and tail rotors and determine how speed, torque and power train alignment is achieved</td>
</tr>
<tr>
<td>P2</td>
<td>describe the function of engine control and fuel metering systems</td>
<td>M2 explain the operation of a turbo-shaft engine lubrication and fuel system</td>
<td>D2 carry out a real or simulated rigging operation on a helicopter main or tail rotor flying control system using the appropriate tools and manuals.</td>
</tr>
<tr>
<td>P3</td>
<td>identify four engine monitoring systems and describe the information each one is indicating</td>
<td>M3 remove, examine, refit and align main and tail rotor transmission components in a real or simulated environment</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>state the principles of a turbo-shaft engine and compare relationships in the gas flow through the engine</td>
<td>M4 explain how airframe alignment is maintained during manufacture or repair and how a symmetry check is carried out.</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>describe the construction of the main components of a turbo-shaft engine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Assessment and grading criteria

<table>
<thead>
<tr>
<th>To achieve a pass grade the evidence must show that the learner is able to:</th>
<th>To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:</th>
<th>To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P6</strong> identify the three types of main rotor heads and describe the operation of a fully articulated head</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P7</strong> describe the components used to obtain main and tail rotor drive and their arrangement on a typical helicopter</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P8</strong> describe helicopter structures, their constructional features and classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P9</strong> identify the assembly methods and alignment techniques used in helicopter structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P10</strong> identify the three helicopter controls used during flight and describe how they achieve control about the three axes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P11</strong> identify the main components and types of controls and components used in the construction of flight control systems on a typical helicopter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Essential guidance for tutors

Delivery

Delivery of this unit should be designed to give learners a thorough understanding of rotary wing aircraft engines, controls and airframes.

When delivering the unit content associated with aircraft engines tutors should concentrate on the turbo-shaft engine, as this is the most common engine in use on helicopters. The operation and control of the engine should be covered in sufficient detail that learners are aware of how power is taken from the engine along with the methods used to control and monitor the operation of the engine. Learners will need to be given access to gas turbine engines so that the construction of components and sections can be examined and explored. Single and double or even triple engine layouts should be considered when looking at the control and monitoring of engines.

The main rotor controls for a single main rotor helicopter have many common components. The general layout of the controls and the subtle differences between the spider arms, swashplates and non-rotating components should be examined so that learners will feel confident when faced by either type or system. There should be sufficient access to main and tail rotor controls on a helicopter to allow real or simulated rigging procedures to be undertaken on them. These should also be used to demonstrate how lift is generated and manipulated to give directional flight and the interaction required from all three controls to gain controlled flight.

The layout of the transmission system from the engine(s) to the main and tail rotor gearboxes and to the blades should be investigated by comparing two different helicopters with sufficiently differing layouts. For this reason it may be preferable to use a single engine and a twin engine helicopter where possible. One of the examples used should be available for real or simulated work so that fitting work on the systems may be carried out. This should also ensure that one type of main rotor head will be available for examination so that learners can determine how the final run of the control system is connected to the blades, how lift and thrust forces produced are carried back through to the airframe and how undesirable forces are resolved. All aspects of the transmission system (power train) should be explored so that the student will develop a thorough understanding of the requirements of the systems.

The construction of the airframe as a support for the transmission and flight control systems along with its purpose of carrying a payload should be considered holistically to integrate all the system requirements. Emphasis should be placed on the load carrying ability of the various airframe constructions and the need to fit transmission components and flying control components in positions that ensure the integrity of the systems. The interaction of the airframe, control systems and transmission systems should be stressed to reinforce the necessity of design with learners. The layout and construction of the main rotor gearbox due to the interaction of the control system used or vice-versa and the necessity of flexibility within the transmission system (power train) and rigidity within the control system should be explored. This will enable the students to understand the complexity of the helicopter as a fully integrated collection of independent systems.

Note that the use of ‘eg’ in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an ‘eg’ needs to be taught or assessed.
Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

<table>
<thead>
<tr>
<th>Topic and suggested assignments/activities and/assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whole-class teaching:</strong></td>
</tr>
<tr>
<td>• introduction to unit content, scheme of work and assessment strategy</td>
</tr>
<tr>
<td>• in an aircraft environment, explain and familiarise learners with helicopters, engines, transmissions (power trains), flying controls and structures</td>
</tr>
<tr>
<td>• in an aircraft maintenance environment demonstrate the constructional arrangements of engines and differing engine controls (FADEC)</td>
</tr>
<tr>
<td>• explain construction of engine monitoring systems, EGT, N1, N2, EGT, Ng, Nf and engine oil and fuel systems</td>
</tr>
<tr>
<td>• explain Newton’s law, Brayton cycle, force, work, power, energy and velocity of gas flows</td>
</tr>
<tr>
<td>• compare compressor designs, ice protection, stalling and surging and airflow control, variable inlet guide vanes, bleed bands etc</td>
</tr>
<tr>
<td>• compare combustion designs, principles and turbine designs, stress and creep. Examine gearbox arrangements.</td>
</tr>
</tbody>
</table>

**Individual activity:**

• investigate (using manuals and related documents) engine layout and construction comparing different engines where available.

**Prepare and carry out Assignment 1: Helicopter Turbo-shaft Engines (P1, P2, P3, P4, P5, M1, M2)**

**Whole-class teaching:**

• identify and compare different rotor head designs and features. Examine and compare gearboxes and powertrains, speeds of shafts and rotors

• a real or simulated drivetrain component removal, fit and installation.

**Group activity:**

• view a helicopter to examine powertrains and various components within transmissions and gearboxes.

**Prepare for and carry out Assignment 2: Helicopter Rotor Transmission Systems (P6, P7, M3, D1)**

**Whole-class teaching:**

• identify helicopter structures, constructional features and explain classification of structures

• explain the assembly methods and alignment techniques used for the construction of helicopter structures.

**Industrial visit:**

• view helicopter structure assembly methods.

**Prepare for and carry out Assignment 3: Helicopter Structures (P8, P9, M4)**
**Topic and suggested assignments/activities and/assessment**

**Whole-class teaching:**
- demonstrate the three flying controls and functionally move all controls to reflect the actions on the rotors
- explain use of inverted airfoils (elevators) to aid reduction of airframe drag and re-positioning of tail rotor gearbox angle to improved C of G range and overall lift component, eg Blackhawk
- detail and identify control components within flying controls and how they interact with other controls.

**Individual activity:**
- in a real or simulated environment carry out rigging operations on main or tail rotor controls using appropriate tools and manuals.

**Prepare for and carry out Assignment 4: Helicopter Flight Control Systems (P10, P11, D2)**

Feedback on assessment and unit review.

**Assessment**

This unit could be assessed through the use of four assignments incorporating a practical exercise or simulation.

The criteria covering learning outcome 1 (P1, P2, P3, P4, P5, M1 and M2) are probably best assessed using a formal written assignment. This assignment would require learners to describe a turbo-shaft engine in terms of its layout and operation and the function and operation of the engine control and fuel metering systems (P1 and P2). They should then develop this to explain the full working cycle of the engine with reference to the engine modules and the free turbine (M1). They should include the gas flow relationships at all stages through the engine (P4), whilst considering lubrication systems (M2) and the monitoring systems employed on the engine (P3).

P5 is concerned with the physical layout of the engine in relation to its attachment to the first part of the transmission system and the free turbine take off position. Learners’ descriptions will need to include inlet, compressor, combustion section, turbine section and exhaust components and free turbine and main engine output gearbox arrangements.

This can link to learning outcome 2 (P6, P7, M3 and D1) which is concerned with the transmission of the power from the engine to the main and tail rotor hubs and how the transmission is installed and aligned on the helicopter. Evidence for this outcome is likely to come through a written assignment. Learners will need to be shown the three types of main rotor head but should concentrate on the fully articulated head (P6) as this is the more complex and requires a greater amount of servicing. The description given for P7 should include any relevant ancillary systems, systems for rotor spread and fold, bearings, seals and lubrication.

An examination of more than one helicopter type will be necessary for learners to compare transmission (powertrain) layouts and power transmission (D1). Practical work or simulated work on at least one helicopter type will allow learners to display their ability to fit and align various transmission components as necessary (M3).
The main rotor head construction will provide a link to the control systems at learning outcome 4 and the fitting of most of the transmission components will provide a link to learning outcome 3.

Learning outcome 3 (P8, P9 and M4) should be integrated with the other outcomes to enable learners to understand the structural requirements and classification of the airframe (P8), especially at the mounting points for the engine, transmission components and flying control components. Learners need to understand alignment requirements and methods used (P9) to achieve the correct orientation of aerodynamic surfaces and transmission components and be able to explain how this is achieved and checked (M4) during manufacture or repair.

Learning outcome 4 is intended to cover the construction, layout and operation of the main flying controls rather than the aerodynamics of flight, apart from the basic directional control about the flight axes (P10). Learners will be able to cover the main components and types of control (P11) by means of a formal assignment that investigates the layout of the control system on one aircraft type. A sufficiently complete control system must be available to allow learners to carry out practical or simulated rigging activities (D2). This does not have to be a full rig of the flying controls but should reflect the amount of rigging that is required after various maintenance procedures.
Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Pearson assignments to meet local needs and resources.

<table>
<thead>
<tr>
<th>Criteria covered</th>
<th>Assignment title</th>
<th>Scenario</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1, P2, P3, P4, P5, M1, M2</td>
<td>Helicopter Turbo-shaft Engines</td>
<td>A written explanation of the principles of the turbo-shaft engine.</td>
<td>Written response to set tasks.</td>
</tr>
<tr>
<td>P6, P7, M3, D1</td>
<td>Helicopter Rotor Transmission Systems</td>
<td>A formal written assignment and a practical/simulated task.</td>
<td>Written response to set tasks with a practical task for M3. Witness statements will be required for practical task.</td>
</tr>
<tr>
<td>P8, P9, M4</td>
<td>Helicopter Structures</td>
<td>A formal written assignment where access to a helicopter will be most beneficial.</td>
<td>Written response to set tasks.</td>
</tr>
<tr>
<td>P10, P11, D2</td>
<td>Helicopter Flight Control Systems</td>
<td>A formal written (assignment) and practical/simulated tasks where access to a helicopter or part control system is required.</td>
<td>Written response to set tasks with a practical task for D2. Witness statements will be required for practical work.</td>
</tr>
</tbody>
</table>
Essential resources

Access to the following resources is considered essential to meet the learning outcomes:

- a range of helicopter components, particularly power plants, transmission (powertrain) components, main rotor heads and tail rotors
- relevant data books and manufacturers’ specifications, aircraft publications and manuals and quality control procedures
- real or training centre helicopter, in a real or training helicopter maintenance environment.

Indicative reading for learners

Textbooks


Other publications

Air Publications – *101 Series of manuals and aircraft engineering publications* (Military)

ATA 100 Series, specialist publications sanctioned by EASA (European Aviation Safety Agency)
13 Further information and useful publications

To get in touch with us visit our ‘Contact us’ pages:

- Edexcel, BTEC and Pearson Work Based Learning contact details: qualifications.pearson.com/en/support/contact-us
- books, software and online resources for UK schools and colleges: www.pearsonschoolsandfecolleges.co.uk

Key publications:
- Adjustments for candidates with disabilities and learning difficulties – Access and Arrangements and Reasonable Adjustments, General and Vocational qualifications (Joint Council for Qualifications (JCQ))
- Equality Policy (Pearson)
- Recognition of Prior Learning Policy and Process (Pearson)
- UK Information Manual (Pearson)
- UK Quality Vocational Assurance Handbook (Pearson).

All of these publications are available on our website.

Publications on the quality assurance of BTEC qualifications are available on our website.

Our publications catalogue lists all the material available to support our qualifications. To access the catalogue and order publications, please visit our website.

Additional resources

If you need further learning and teaching materials to support planning and delivery for your learners, there is a wide range of BTEC resources available.

Any publisher can seek endorsement for their resources, and, if they are successful, we will list their BTEC resources on our website, qualifications.pearson.com
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- planning for assessment and grading
- developing effective assignments
- building your team and teamwork skills
- developing learner-centred learning and teaching approaches
- building in effective and efficient quality assurance systems.

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- Ask the Expert: submit your question online to our Ask the Expert online service and we will make sure your query is handled by a subject specialist.

Please visit, qualifications.pearson.com/en/support/contact-us
Annexe A: Assessment Strategy

Apprenticeship Standards for the Aerospace and Aviation Sector

Assessment Strategy for Employers, Training Providers and Awarding Organisations

Version 3
Introduction

Employers in the aerospace and aviation sector have produced this Qualification Assessment Strategy to:

- support the implementation and delivery of the Apprenticeship Standard in a way that is appropriate, relevant, feasible, manageable and affordable in a wide range of employer contexts
- provide clarity for awarding organisations on what constitutes competent performance
- encourage and promote consistent assessment of competence and technical knowledge requirements
- promote cost-effective delivery and assessment plans
- motivate learners to always maintain a high level of skills, knowledge and behaviours throughout the apprenticeship and not just to do enough to satisfy the minimum requirements, in the knowledge that they will be continually assessed, leading to a final end-point assessment with a technical interview (viva) and supported by the achievement of competence and technical-knowledge qualifications along with a portfolio of evidence
- add value to both the apprentice and the employer, by complementing and building on normal company performance management and development tools, including regular performance reviews
- enable and encourage progression and continuing professional development by being linked to professional recognition
- position the apprenticeship not just as a job, but as the starting point for a career in the sector – the assessment at the end marks a clear recognition of achievements, on which the individual can build
- select assessment methods that will ensure relevance and consistency, irrespective of the specific job role of the apprentice
- ensure costs and practicalities will be appropriate and proportionate to large as well as Small and Medium Enterprise (SME) employers including those with large or small numbers of apprentices.

This document also provides definitions for:

- the qualifications and experience required for assessors/trainers/teachers and verifiers
- the assessment environment for the Foundation and Development Phase Occupational Competence Qualifications
- access to assessment

and requirements relating to:

- carrying out occupational competence assessments
- performance evidence requirements for occupational competence
- assessing knowledge and understanding
- use of witness testimonies
- continuing professional development
- quality control of assessment.
Section 1

Occupational Competence Qualifications (Foundation and Development Phase)

Assessor requirements to demonstrate effective assessment practice
Assessment must be carried out by competent assessors that, as a minimum, hold the QCF Level 3 Award in Assessing Competence in the Work Environment. Current and operational assessors that hold units D32 and/or D33 or A1 and/or A2 as appropriate to the assessment being carried out will not be required to achieve the QCF Level 3 Award as they are still appropriate for the assessment requirements set out in this Assessment Strategy. However, they will be expected to regularly review their skills, knowledge and understanding and, where applicable, undertake continuing professional development to ensure that they are carrying out workplace assessment to the most up-to-date Employer Units of Competence (EUCs).

Assessor technical requirements
Assessors must be able to demonstrate that they have verifiable, relevant and sufficient technical competence to evaluate and judge performance and knowledge evidence requirements as set out in the relevant outcomes in the Employer Units of Competence.

This will be demonstrated either by holding a relevant technical qualification or by proven industrial experience of the technical areas to be assessed. The assessor’s competence must, at the very least, be at the same level as that required of the apprentice in the units being assessed.

Assessors must also be fully conversant with the awarding organisation’s assessment recording documentation used for the Employer Units of Competence against which the assessments and verification are to be carried out, plus any other relevant documentation and systems and procedures to support the Quality Assurance (QA) process.

Verifier requirements (internal and external)
Internal QA (internal verification) must be carried out by competent verifiers that, as a minimum, hold the QCF Level 4 Award in the Internal Quality Assurance of Assessment Processes and Practices.

Current and operational internal verifiers that hold internal verification units V1 or D34 will not be required to achieve the QCF Level 4 Award, as they are still appropriate for the verification requirements set out in this Assessment Strategy. Verifiers must be familiar with, and preferably hold, either the nationally recognised assessor units D32 and/or D33 or A1 and/or A2 or the QCF Level 3 Award in Assessing Competence in the Work Environment.

External QA (external verification) must be carried out by competent external verifiers that as a minimum hold the QCF Level 4 Award in the External Quality Assurance of Assessment Processes and Practices.

Current and operational external verifiers that hold external verification units V2 or D35 will not be required to achieve the QCF Level 4 Award as they are still appropriate for the verification requirements set out in this Assessment Strategy. Verifiers must be familiar with, and preferably hold, either the nationally recognised assessor units D32 and/or D33 or A1 and/or A2 or the QCF Level 3 Award in Assessing Competence in the Work Environment.

External and internal verifiers will be expected to regularly review their skills, knowledge and understanding and where applicable undertake continuing
professional development to ensure that they are carrying out workplace quality assurance (verification) of assessment processes and practices to the most up-to-date Employer Units of Competence.

Verifiers, both internal and external, will also be expected to be fully conversant with the terminology used in the Employer Units of Competence against which the assessments and verification are to be carried out, the appropriate regulatory body’s systems and procedures and the relevant awarding organisation’s documentation, systems and procedures within which the assessment and verification is taking place.

**Specific technical requirements for internal and external verifiers**

Internal and external verifiers for the Employer Units of Competence must be able to demonstrate verifiable, sufficient and relevant industrial experience, and must have a working knowledge of the processes, techniques and procedures that are used in the engineering industry.

The table below and on the following page show the recommended levels of technical competence for assessors, internal verifiers and external verifiers.

**Technical requirements for assessors and verifiers**

<table>
<thead>
<tr>
<th>Position</th>
<th>Prime activity requirements</th>
<th>Support activity requirements</th>
<th>Technical requirements (see Notes section below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessor</td>
<td>Assessment skills</td>
<td>IV systems</td>
<td>Technical competence in the areas covered by the Employer Units of Competence being assessed</td>
</tr>
<tr>
<td>Internal verifier</td>
<td>Verification skills</td>
<td>Assessment knowledge</td>
<td>Technical <em>understanding</em> of the areas covered by the Employer Units of Competence being verified</td>
</tr>
<tr>
<td>External verifier</td>
<td>Verification skills</td>
<td>Assessment understanding</td>
<td>Technical <em>awareness</em> of the areas covered by the Employer Units Competence being verified</td>
</tr>
</tbody>
</table>
Notes

1. Technical competence is defined here as a combination of practical skills and knowledge, as well as the ability to apply both of these in familiar and new situations, within a real working environment.

2. Technical understanding is defined here as having a good understanding of the technical activities being assessed, together with knowledge of relevant health and safety implications and requirements of the assessments.

3. Technical awareness is defined here as a general overview of the subject area, sufficient to ensure that assessment and evidence are reliable and that relevant health and safety requirements have been complied with.

4. The competence required by the assessor, internal verifier and external verifier roles, in the occupational area being assessed, is likely to exist at three levels as indicated by the shaded zones in the following table.

<table>
<thead>
<tr>
<th>Technical Competence Required by:</th>
<th>An ability to discuss the general principles of the competences being assessed</th>
<th>An ability to describe the practical aspects of the competence being assessed</th>
<th>An ability to demonstrate the practical competences being assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal verifier</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External verifier</td>
<td></td>
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</tr>
</tbody>
</table>

Assessment environment of the Employer Units of Competence (EUCs) in the Foundation phase of the apprenticeship

The EUCs are intended to have a wide application throughout the aerospace and aviation sector. It is therefore necessary to have a flexible approach to the environment in which the Employer Units of Competence are delivered and assessed during the foundation phase of the Apprenticeship.

There is much to be gained by acquiring the basic engineering competencies required in the foundation phase of the Apprenticeship while working in a sheltered but realistic environment such as in a training centre or college. This is due to an ongoing emphasis on safety-critical work activities and the need to ensure flexibility of assessment opportunities to both maintain and enhance the provision of competent personnel within the aerospace and aviation industry. These assessment conditions will allow a minimum safe level of skills, knowledge and understanding to be achieved and demonstrated by the apprentice before being exposed to the hazards of the industrial environment, therefore minimising the risk of injury to themselves and other employees.

For the above reasons, the assessment of the apprentice’s competence in a sheltered but realistic environment is acceptable for the EUCs included in the foundation phase of the Apprenticeship, where the environment replicates that expected in industry.

Where applicable, the machinery, tools, materials, equipment and resources used must be representative of industry standards and there must be sufficient equipment/resources available for each apprentice to demonstrate their competence on an individual basis. Workpieces or work outcomes assessed must be the apprentice’s own work and should be actual work examples that combine the
skills and techniques required by the Employer Units of Competence so that achievement will properly reflect the apprentice's capabilities.

Assessors must ensure that the competency assessed in a simulated environment is fully transferable to the workplace. Other aspects that should be considered include:

- environmental conditions, such as lighting conditions, noise levels and the presence of hazards
- pressure of work, such as time constraints and repetitive activities
- producing actual workpieces or work outcomes, the consequences of making mistakes and the effect these have on customer, supplier and departmental relationships.

**Assessment environment of the Employer Units of Competence in the development phase of the apprenticeship**

The evidence put forward for the Employer Units of Competence can only be regarded valid, reliable, sufficient and authentic if achieved and obtained in the working environment where the apprentice is employed and be clearly attributable to the apprentice. However, in certain circumstances, simulation/replication of work activities may be acceptable, but must be kept to an absolute minimum.

The use of high-quality, realistic simulations/replication, which impose pressures consistent with workplace expectations, should only be used in relation to the assessment of the following:

- rare or dangerous occurrences, such as those associated with health, safety and the environment issues, emergency scenarios and rare operations at work
- the response to faults and problems for which no opportunity has presented for the use of naturally occurring workplace evidence of learners’ competence
- aspects of working relationships and communications for which no opportunity has presented for the use of naturally occurring workplace evidence of learners’ competence.

Simulations/replications will require prior approval from the specific awarding organisation and should be designed in accordance with the following parameters:

- the environment in which simulations take place must be designed to match the characteristics of the working environment
- competencies achieved via simulation/replication must be transferable to the working environment
- simulations that are designed to assess competence in dealing with emergencies, accidents and incidents must be verified as complying with relevant health, safety and environmental legislation by a competent health and safety/environmental control officer before being used
- simulated activities should place apprentices under the same pressures of time, access to resources and access to information as would be expected if the activity was real
- simulated activities should require apprentices to demonstrate their competence using plant and/or equipment used in the working environment
- simulated activities that require interaction with colleagues and contacts should require the apprentice to use the communication media that would be expected at the workplace
• for health and safety reasons simulations need not involve the use of genuine substances/materials. Any simulations which require the apprentice to handle or otherwise deal with materials substances/should ensure that the substitute takes the same form as in the workplace.

Access to assessment
There are no entry requirements required for the Employer Units of Competence, unless this is a legal requirement of the process or the environment the apprentice is working in. Assessment is open to any apprentice who has the potential to reach the assessment requirements set out in the relevant units.

Aids or appliances that allow students with special educational needs, disabilities or temporary injuries, may be used during assessment, providing they do not compromise the standard required.

Carrying out assessments of the occupational competence qualifications
The EUCs have been specifically developed to cover a wide range of activities. The evidence produced for the units will, therefore, depend on the skills and knowledge required by employers and specified in the Apprentices Training Plan. The Skills section of the Employer Units of Competence makes reference to a number of optional items in the units (for example ‘any three from five’). This is the minimum standard set by employers.

Where the unit requirements give a choice of optional items, assessors should note that apprentices do not need to provide evidence of the other items to complete the unit (in the example above, three items from five), unless specified by the employer.

Performance evidence requirements of the occupational competence qualifications
Performance evidence must be the main form of evidence gathered. In order to demonstrate consistent competent performance for a unit, a minimum of three different examples of performance of the unit activity will be required. Items of performance evidence often contain features that apply to more than one unit, and can be used as evidence in any unit where they are suitable.

Performance evidence must be:
• products of the learner’s work, such as items that have been produced or worked on, plans, charts, reports, standard operating procedures, documents produced as part of a work activity, records or photographs of the completed activity together with:
• evidence of the way the apprentice carried out the activities, such as witness testimonies, assessor observations or authenticated apprentice reports of the activity undertaken.

Competent performance is more than just carrying out a series of individual set tasks. Many of the units in the foundation phase contain statements that require the learner to provide evidence that proves they are capable of combining various features and techniques. Where this is the case, separate fragments of evidence would not provide this combination of features and techniques and, therefore, will not be acceptable as demonstrating competent performance.

If there is any doubt as to what constitutes suitable evidence the internal/external verifier should be consulted.
Example

Foundation Unit 10: Preparing Aircraft Detail Assemblies

Unit-specific additional assessment requirements:

Specific unit requirements
In order to prove their ability to combine different aircraft detail assembly operations, at least one of the assemblies produced must be of a significant nature, and must contain a minimum of four of the components listed in the skills section, paragraph 2.

Assessing knowledge and understanding requirements in the occupational competence qualifications

Knowledge and understanding are key components of competent performance, but it is unlikely that performance evidence alone will provide enough evidence in this area. Where the apprentice’s knowledge and understanding are not apparent from performance evidence, they must be assessed by other means and be supported by suitable evidence.

Knowledge and understanding can be demonstrated in a number of different ways. It is recommended that oral questioning and practical demonstrations are used perhaps while observing the apprentice undertake specific tasks, as these are considered the most appropriate for these units. Assessors should ask enough questions to make sure that the apprentice has an appropriate level of knowledge and understanding, as required by the unit.

Evidence of knowledge and understanding will not be required for those items in the skills section of the Employer Units of Competence that have not been selected by the employer.

The achievement of the specific knowledge and understanding requirements in the units may not simply be inferred by the results of tests, exams or assignments from other units such as in the technical knowledge qualifications or other training programmes. Where evidence is submitted from these sources, the assessor must, as with any assessment, make sure the evidence is valid, reliable, authentic, directly attributable to the apprentice, and meets the full knowledge and understanding requirements of the unit.

Where oral questioning is used, the assessor must retain a record of the questions asked, together with the apprentice’s answers.

Witness testimony

Where observation is used to obtain performance evidence, this must be carried out against the unit assessment criteria. Best practice would require that such observation is carried out by a qualified assessor. If this is not practicable, then alternative sources of evidence may be used.

For example, the observation may be carried out against the assessment criteria by someone else that is in close contact with the apprentice. This could be a team leader, supervisor, mentor or line manager who may be regarded as a suitable witness to the apprentice’s competency. However, the witness must be technically competent in the process or skills that they are providing testimony for, to at least the same level of expertise as that required of the apprentice. It will be the responsibility of the assessor to make sure that any witness testimonies accepted as evidence of the apprentice’s competency are reliable, auditable and technically valid.
Maximising opportunities to use assessment evidence

One of the critical factors required in order to make this assessment strategy as efficient and effective as possible and to ease the burden of assessment, is the assessor’s ability and expertise to work in partnership with the apprentice and their employer to provide advice and guidance on how to maximise opportunities to cross-reference performance and knowledge evidence to all relevant Employer Units of Competence. For example, if a knowledge statement is repeated in a number of separate Employer Units of Competence and the expected evidence/response to that statement is the same, including the context, then the same piece of evidence should be cross-referenced to the appropriate units.
Section 2

Technical knowledge qualifications (foundation and development phase)

Teacher/trainer/lecturer/assessor requirements

Staff must:
- have relevant experience in teaching/training/assessing
  or
- hold, or are working towards an appropriate teaching/training/assessing qualification
  and
- be technically knowledgeable in the area(s) for which they are delivering training/assessing, with appropriate qualifications
- be familiar with the Engineering Technician (UK specification of EngTech) requirements when delivering/assessing Level 3 – they will be required to provide a signed declaration confirming they have read and understood the EngTech specification and the evidence requirements to meet the EngTech criteria.

Internal quality assurance requirements

Staff must:
- have experience in quality management/internal verification
  or
  hold or be working towards an appropriate internal quality assurance qualification
  and
  be familiar with the occupation and technical content covered within the qualification
  be familiar with the EngTech requirements when delivering/assessing Level 3 – they will be required to provide a signed declaration confirming they have read and understood the EngTech specification and the evidence requirements to meet the EngTech criteria.

External quality assurance requirements

Staff must:
- have experience in quality management/external verification
- hold or be working towards an appropriate external quality assurance qualification
- be familiar with the occupation and technical content covered within the qualifications
- be familiar with the EngTech requirements for Level 3 and understand the evidence requirements to meet the EngTech criteria.
Assessments

The qualifications will include both internal and external assessments, which could include a range of different methods such as:

- practical assessments
- short-answer questions
- written or multiple-choice tests
- paper-based or online assessments
- other appropriate assessment methods.

The assessment methods to be used will be agreed across all awarding organisations (AOs) involved in the development of the units.

Grading

The knowledge qualifications will be graded pass, merit or distinction in line with the grading criteria to be agreed across all AOs involved in the development of the units.

The agreed grading criteria will be made available to providers, teachers, assessors and learners to ensure they are fully aware of the achievement requirements for each grade. Please refer to the specifications from the individual AOs.
Section 3

General requirements

Continuing professional development (CPD)
Centres must support their staff to ensure that they have current technical knowledge of the occupational area; that delivery, mentoring, training, assessment and verification are in line with best practice, technical advancements and that they will take account of any national or legislative developments. There must be an auditable individual CPD plan in place for all staff assessing and verifying the qualifications within the aerospace and aviation foundation and development phases; the plan must meet the relevant provider and aerospace and aviation employer requirements.

Assessors/teachers/trainers/lecturers (as applicable):
- must understand the EngTech requirements when providing guidance to assessors. They will be required to provide a signed declaration confirming they have read and understood the EngTech specification and the evidence requirements to meet the EngTech criteria as it is a mandatory requirement that all apprentices complete the Aerospace and Aviation Apprenticeship Standard – Engineering Technician Performance Indicators Recording Document (currently in development). The Engineering Technician (UK specification) can be found at www.engc.org.uk
- must understand the requirements of the Aerospace and Aviation Apprenticeship Standard – End of Scheme Assessment Recording Document (currently in development).

Quality control of assessment

General
There are two major points where an awarding organisation interacts with the centre in relation to the external quality control of assessment and these are:
- approval – when a centre takes on new qualifications/units, the awarding organisation, normally through an external verifier (EV), ensures that the centre is suitably equipped and prepared to deliver the new units/qualification
- monitoring – throughout the ongoing delivery of the qualification/units the awarding organisation, through EV monitoring and other mechanisms must maintain the quality and consistency of assessment of the units/qualification.

Approval
In granting approval, the awarding organisation, normally through its external verifier (EV), must ensure that the prospective centre:
- meets the requirements of the qualification regulator
- has sufficient and appropriate physical and staff resources
- meets relevant health and safety and/or equality and access requirements
- has a robust plan for the delivery of the qualification/units.

The awarding organisation may visit the centre to view evidence or may undertake this via other means.

The awarding organisation must have a clear rationale for the method(s) deployed.
Monitoring

Each AO, through EV monitoring and other mechanisms, must ensure:

- that a strategy is developed and deployed for the ongoing AO monitoring of the centre. This strategy must be based on an active risk assessment of the centre. In particular, the strategy must identify the apprentice, assessors and internal verifier sampling strategy to be deployed and the rationale behind this
- that the centre’s internal QA processes are effective in assessment
- that sanctions are applied to a Centre where necessary and that corrective actions are taken by the centre and monitored by the AO/EV
- that reviews of the AO’s external auditing arrangements are undertaken.

Notes

a) It is recognised that each AO will have its own guidance and procedure on the internal and external QA process applied to these qualifications. See individual AO websites for further information.

b) This assessment strategy is a ‘work in progress’ and will be amended and re-issued as the competence and technical knowledge qualifications and assessment methodologies are developed and modified, i.e. it is hoped that it will be adapted to meet the requirements of the aerospace Maintenance, Repair and Overhaul (MRO) sector as their standards and qualification requirements are developed.

c) The aerospace and aviation sector is mindful that its apprenticeships are and must be available across all four Nations in the UK. The sector has ensured that the Employer Occupational Brief (EOB) and the associated Employer Units of Competence are directly aligned to the existing format and content of the sector’s National Occupational Standards (NOS).