
Pearson BTEC

Pearson BTEC
International Level 2 in
# Engineering

L2

# Specification

*First teaching from September 2020*

Issue 1

# Pearson
# BTEC International
# Level 2 Qualifications
# in Engineering

## Specification

First teaching September 2022

Issue 1

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

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# Welcome

With a track record built over 40 years of learner success, our BTEC International Level 2 qualifications are recognised internationally by governments and employers. These qualifications are designed to enhance the curriculum and prepare learners for the ever-changing world of work. BTEC International Level 2 qualifications allow learners to progress to study at Level 3 and above or to the workplace.

## Career-ready education

BTECs enable a learner-centred approach to education, with a flexible, unit-based structure and knowledge applied to project-based assessments. BTECs focus on the holistic development of the practical, interpersonal and thinking skills required to be successful in employment and higher education.

When creating the BTEC International Level 2 qualifications in this suite, we worked with many employers, colleges and schools to ensure that we met their needs.

BTEC addresses these needs by offering:

- a range of BTEC qualification sizes, each with a clear purpose, so that there is something to suit each learner's choice of study programme and progression plans
- internationally relevant content, which is closely aligned with employer and further education needs
- assessments and projects chosen to help learners progress; this means that some assessments and projects are set by you to meet local needs, while others are set by Pearson, ensuring a core of skills and understanding common to all learners.

We provide a full range of support, both resources and people, to ensure that learners and teachers have the best possible experience during their course. See *Section 10 Resources and support*, for details of the support we offer.

# Contents

# Introduction to the BTEC International Level 2 qualifications for the engineering sector

This specification contains all the information you need to deliver the Pearson BTEC International Level 2 qualifications in Engineering. We also refer you to other handbooks and policies. This specification includes all the units for these qualifications.

These qualifications are part of the suite of engineering qualifications offered by Pearson. In this suite, there are qualifications that focus on different progression routes, allowing learners to choose the one best suited to their aspirations. These qualifications are not regulated in England.

All qualifications in the suite share some common units and assessments, which gives learners some flexibility in moving between sizes.

In the engineering sector these qualifications are:

Pearson BTEC International Level 2 Award in Engineering

Pearson BTEC International Level 2 Certificate in Engineering

Pearson BTEC International Level 2 Extended Certificate in Engineering

Pearson BTEC International Level 2 Extended Certificate in Mechatronics

Pearson BTEC International Level 2 Extended Certificate in Vehicle Technology

Pearson BTEC International Level 2 Diploma in Engineering

Pearson BTEC International Level 2 Diploma in Mechatronics

Pearson BTEC International Level 2 Diploma in Vehicle Technology.

This specification signposts the other essential documents and support that you need as a centre in order to deliver, assess and administer the qualifications, including the staff development required. A summary of all essential documents is given in *Section 7 Administrative arrangements*. Information on how we can support you with these qualifications is given in *Section 10 Resources and support*.

The information in this specification is correct at the time of publication.

## Qualifications, sizes and purposes at a glance

| Title | Size and structure | Summary purpose |
|---|---|---|
| **Pearson BTEC International Level 2 Award in Engineering** | 120 GLH<br>Equivalent in size to one International GCSE.<br>120 GLH, of which 60 GLH are mandatory (30 GLH assessed by a Pearson Set Assignment).<br>Mandatory content (50%). | This qualification is designed to support learners who want an introduction to the sector through applied learning and for whom an element of engineering would be complementary. The qualification supports progression to further study at Level 3/pre-tertiary education as part of a programme of study that includes BTEC International Level 3 qualifications and/or International A levels. |
| **Pearson BTEC International Level 2 Certificate in Engineering** | 240 GLH<br>Equivalent in size to two International GCSEs.<br>240 GLH, of which 90 GLH are mandatory (60 GLH are assessed by a Pearson Set Assignment) and 150 GLH selected from a given optional unit list.<br>Mandatory content (38%). | This qualification is designed to support learners who are interested in learning about the engineering industry alongside other fields of study, with a view to progressing to a wide range of courses at Level 3/pre-tertiary level, not necessarily in engineering-related subjects. The qualification is designed to be taken as part of a programme of study that includes other appropriate BTEC International Level 2 qualifications or International GCSEs. |
| **Pearson BTEC International Level 2 Extended Certificates in Engineering and Vehicle Technology** | 360 GLH<br>Equivalent in size to three International GCSEs.<br>360 GLH, of which 120 GLH are mandatory (90 GLH are assessed through Pearson Set Assignment) and 240 GLH selected from given optional unit lists.<br>Mandatory content (33%). | This qualification is designed to support learners who want to study Engineering or Vehicle Technology as a substantial element of a one-year, full-time course alongside smaller courses in other subjects, or for those wanting to take a qualification alongside another area of complementary or contrasting study as part of a two-year, full-time study programme.<br>Each qualification would support progression to further education at Level 3/pre-tertiary level if taken as part of a programme of study that included other BTEC International Level 2 qualifications or International A Levels. |

| Title | Size and structure | Summary purpose |
|---|---|---|
| **Pearson BTEC International Level 2 Extended Certificate in Mechatronics** | 360 GLH<br>Equivalent in size to three International GCSEs.<br>360 GLH, of which 240 GLH are mandatory (90 GLH are assessed through Pearson Set Assignment) and 120 GLH selected from given optional unit lists.<br>Mandatory content (66%). | This qualification is designed to support learners who want to study Mechatronics as a substantial element of a one-year, full-time course alongside smaller courses in other subjects, or for those wanting to take a course alongside another area of complementary or contrasting study as part of a two-year, full-time study programme. The qualification would support progression to further education at Level 3/pre-tertiary level if taken as part of a programme of study that included other BTEC International Level 2 qualifications or International A Levels. |
| **Pearson BTEC International Level 2 Diplomas in Engineering and Vehicle Technology** | 480 GLH<br>Equivalent in size to four International GCSEs.<br>480 GLH, of which 150 GLH are mandatory (120 GLH are assessed through Pearson Set Assignments) and 330 GLH selected from the given optional unit lists.<br>Mandatory content (31%). | This qualification is designed to support learners who want to study Engineering or Vehicle Technology as a one-year, full-time course, or for those wanting to take a course alongside another area of complementary or contrasting study as part of a two-year, full-time study programme. The qualification would support progression to Level 3/pre-tertiary level courses if taken as part of a programme of study that included other BTEC International Level 2 qualifications or International GCSEs. |

| Title | Size and structure | Summary purpose |
|---|---|---|
| **Pearson BTEC International Level 2 Diploma in Mechatronics** | 480 GLH<br>Equivalent in size to four International GCSEs.<br>480 GLH, of which 270 GLH are mandatory (120 GLH are assessed through Pearson Set Assignments) and 210 GLH selected from the given optional unit lists.<br>Mandatory content (56%). | This qualification is designed to support learners who want to study Mechatronics as a one-year, full-time course, or for those wanting to take it alongside another area of complementary or contrasting study as part of a two-year, full-time study programme. The qualification would support progression to Level 3/pre-tertiary level courses if taken as part of a programme of study that included other BTEC International Level 2 qualifications or International GCSEs. |

## Structures of the qualifications at a glance

This table shows all the units and the qualifications to which they contribute. The full structure for these Pearson BTEC International Level 2 qualifications in Engineering are shown in *Section 2 Structure*. **You must refer to the full structure to select units and plan your programme.**

**Key**

**Pearson Set Assignment units are shown in bold** | **M** **Mandatory units** | **O** **Optional units**

**E** **Engineering** | **MA** **Mechtronic** | **VT** **Vehicle Technology**

| Unit (number and title) | Unit size (GLH) | Award (120 GLH) | Certificate (240 GLH) | Extended Certificate (360 GLH) | | | Diploma (480 GLH) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | E | MA | VT | E | MA | VT |
| 1 Working Safely and Effectively in Engineering | 30 | M | M | M | M | M | M | M | M |
| **2 Engineering Thinking Skills to Create Solutions** | 30 | M | M | M | M | M | M | M | M |
| **3 Investigating an Engineering Product** | 30 | O | M | M | M | M | M | M | M |
| **4 Engineering Maintenance** | 30 | O | O | M | M | M | M | M | M |
| **5 Mathematics for Engineering Technicians** | 30 | O | O | O | O | O | M | M | M |
| 6 Engineering Materials | 30 | O | O | O | O | O | O | O | O |
| 7 Engineering Drawing | 60 | O | O | O | O | O | O | O | O |
| 8 Machining Techniques | 60 | O | O | O | O | O | O | O | O |
| 9 Engineering Design | 60 | O | O | O | O | O | O | O | O |
| 10 Engineering Fitting and Assembly | 30 | O | O | O | O | O | O | O | O |
| 11 Welding | 60 | | | O | O | O | O | O | O |
| 12 Business Improvement Techniques | 30 | O | O | O | O | O | O | O | O |
| 13 Operations and Maintenance of Mechanical Systems and Components | 60 | | O | O | O | O | O | O | O |
| 14 Fabrication Techniques | 60 | O | O | O | | | O | | |
| 15 Engineering Marking Out | 30 | O | O | O | | | O | | |

*continued overleaf*

| Unit (number and title) | Unit size (GLH) | Award (120 GLH) | Certificate (240 GLH) | Extended Certificate (360 GLH) | | | Diploma (480 GLH) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | E | MA | VT | E | MA | VT |
| 16 Application of Quality Control and Measurement in Engineering | 60 | O | O | O | O | O | O | O | O |
| 17 3D Printing | 60 | O | O | O | O | O | O | O | O |
| 18 Applied Chemistry for Engineers | 30 | | | O | O | O | O | O | O |
| 19 Data Capture and Interpretation | 60 | | O | O | O | O | O | O | O |
| 20 Electrical and Mechanical Science for Engineering | 30 | O | O | O | O | O | O | O | O |
| 21 Renewable Technologies and Sustainability | 60 | O | O | O | O | O | O | O | O |
| 22 Electrical and Electronic Circuit Construction and Testing | 60 | O | O | O | O | O | O | O | O |
| 23 Electronic Devices and Communication Applications | 60 | O | O | O | O | O | O | O | O |
| 24 Operation and Maintenance of Electrical and Electronic Systems and Components | 60 | O | O | O | M | O | O | M | O |
| 25 Computer Numerical Control Programming and Machining | 60 | O | O | O | O | O | O | O | O |
| 26 Robotics | 60 | O | O | O | O | O | O | O | O |
| 27 General Programming | 60 | | O | O | O | O | O | O | O |
| 28 Automated Systems | 60 | O | O | O | M | O | O | M | O |
| 29 Cyber Security in Engineering | 30 | | O | O | O | O | O | O | O |
| 30 Sustainable Vehicle Power and Structure Design | 60 | | | | | O | | | O |
| 31 Vehicle Maintenance Techniques | 60 | | O | O | O | O | O | O | O |
| 32 Vehicle Engine Technology | 60 | | | O | | O | O | | O |
| 33 Vehicle Electrical and Electronic Systems | 60 | | | | O | O | | O | O |
| 34 Hybrid and Electric Vehicles | 60 | | | | | O | | | O |

## Qualification and unit content

Pearson has developed the content of the new BTEC International Level 2 qualifications in Engineering in collaboration with employers and subject experts so that content is up to date and includes knowledge, understanding, skills and personal attributes required in the sector.

The mandatory content ensures that all learners are following a coherent programme of study and that they acquire knowledge, understanding and skills that will be worthwhile and fulfilling, and will also provide a basis for further study at Level 3. Learners are expected to show achievement across mandatory units as detailed in *Section 2 Structure*.

BTEC qualifications encompass applied learning that brings together knowledge and understanding with practical and technical skills. This applied learning is achieved through learners performing vocational tasks that encourage the development of appropriate vocational behaviours and transferable skills. Transferable skills include communication, teamwork and research and analysis, which are valued by employers. Opportunities to develop these skills are signposted in the units.

Our approach provides rigour and balance and promotes the ability to apply learning immediately in new contexts. The units include guidance on approaches to breadth and depth of coverage, which can be modified to ensure that content is current and reflects international variations.

## Assessment

Assessment is designed to fit the purpose and objective of the qualification. It includes a range of assessment types and styles suited to vocational qualifications in the sector. All assessment is internal, but some mandatory units are assessed using Pearson Set Assignments.

### Pearson Set Assignment (PSA) units

Some units in the qualifications are assessed using a Pearson Set Assignment. Each assessment is set by Pearson and is marked by teachers.

Set assignment units are subject to external standards verification processes common to all BTEC units. By setting an assignment for some units, we can ensure that all learners take the same assessment for a specific unit. Learners are permitted to resit set assignment units during their programme. Please see *Section 6 Internal assessment* for further information.

Set assignments are available from June each year and are valid until the end of August in the following year. For detailed information on the Pearson Set Assignment, please see the table in *Section 2 Structure*. For further information on preparing for assessment, see *Section 5 Assessment structure*.

## Internal assessment

All units in the sector are internally assessed and subject to external standards verification. Before you assess you will need to become an approved centre if you are not one already. You will need to prepare to assess using the guidance in *Section 6 Internal assessment*.

For units where there is no Pearson Set Assignment, you select the most appropriate assessment styles according to the learning set out in the unit. This ensures that learners are assessed using a variety of styles to help them develop a broad range of transferable skills. Learners could be given opportunities to:

- write up the findings of their own research
- use case studies to explore complex or unfamiliar situations
- carry out projects for which they have choice over the direction and outcomes
- demonstrate practical and technical skills using appropriate tools/processes, etc.

For these units, Pearson will provide an Authorised Assignment Brief that you can use. You will make grading decisions based on the requirements and supporting guidance given in the units. Learners may not make repeated submissions of assignment evidence. For further information, please see *Section 6 Internal assessment*.

## Language of assessment

Assessment of the units for these qualifications are available in English but can be translated as necessary.

Learners taking the qualification/s may be assessed in sign language where it is permitted for the purpose of reasonable adjustment. For information on reasonable adjustments, see *Section 7 Administrative arrangements*.

## Grading for units and qualifications

Achievement of the qualification requires demonstration of depth of study in each unit, assured acquisition of a range of practical skills required for employment or for progression to higher education, and successful development of transferable skills. Learners who achieve a qualification will have achieved across mandatory units where applicable.

Units are assessed using a grading scale of Distinction (D), Merit (M), Pass (P) and Unclassified (U). All mandatory and optional units contribute proportionately to the overall qualification grade, for example a unit of 60 GLH will contribute double that of a 30 GLH unit.

Qualifications in the suite are graded using a scale of P to D*, **or** PP to D*D*. Please see *Section 9 Understanding the qualification grade* for more details. The relationship between qualification grading scales and unit grades will be subject to regular review as part of Pearson's standards monitoring processes, on the basis of learner performance and in consultation with key users of the qualifications.

# 1 Qualification purpose and progression

## Pearson BTEC International Level 2 qualifications in Engineering

### Who are these qualifications for?

The Pearson BTEC International Level 2 qualifications in Engineering are designed for learners in the 14–19 age group who wish to pursue a career in engineering via Level 3 and then to higher education or through engineering employment from a junior role.

### Which size qualification to choose?

Choosing the most suitable size of qualification will depend on the learner's broader programme of study. For example, a learner who wishes to focus mainly on engineering or vehicle technology may take a Diploma, while a learner who selects a smaller qualification; such as the Award or Certificate, will likely combine it with other qualifications, for example International GCSEs, in order to support their desired progression.

Qualification structures have been designed to enable a learner who starts with the smallest qualification to progress easily to the larger qualifications.

### What do these qualifications cover?

The content of these qualifications has been designed to support progression to particular engineering roles, most likely via further study at Level 3 and then through higher-education routes in the particular areas.

All learners will be required to take mandatory content that is directly relevant to progression routes in all of the identified areas.

In addition, learners can take optional units that support the progression routes identified in the qualification titles.

### What could these qualifications lead to?

These qualifications support progression to further study in engineering; for example, courses in:

- BTEC International Level 3 qualifications in Engineering
- BTEC International Level 3 qualifications in Electrical and Electronic Engineering
- BTEC International Level 3 qualifications in Mechanical Engineering
- BTEC International Level 3 qualifications in Digital Engineering
- BTEC International Level 3 qualifications in Manufacturing Engineering
- BTEC International Level 3 qualifications in Aeronautical Engineering
- BTEC International Level 3 qualifications in Mechatronic Engineering.

### How do these qualifications provide transferable skills?

In the BTEC International Level 2 units, there are opportunities during the teaching and learning phase for learners to practise developing transferable skills. Where we refer to transferable skills in this specification, we are generally referring to skills in the following three main categories:

- **cognitive and problem-solving skills** – using critical thinking, approaching non-routine problems, applying expert and creative solutions, using systems and technology
- **interpersonal skills** – communicating, working collaboratively, negotiating and influencing, self-presentation
- **intrapersonal skills** – self-management, adaptability and resilience, self-monitoring and development.

There are also specific requirements in some units for assessment of these skills where relevant, for example where learners are required to undertake real or simulated activities. These skills are indicated in the units and in *Appendix 1: Transferable employability skills*.

### How do the qualifications provide transferable knowledge and skills for further and higher education?

All BTEC International Level 2 qualifications provide transferable knowledge and skills that prepare learners for progression to university. The transferable skills that universities value include:

- the ability to learn independently
- the ability to research actively and methodically
- the ability to give presentations and be active group members.

BTEC learners can also benefit from opportunities for deep learning, where they are able to make connections across units and select areas of interest for detailed study.

# 2 Structure

## Qualification structures

The structures presented below are for the following qualifications in this specification:

- Pearson BTEC International Level 2 Award in Engineering
- Pearson BTEC International Level 2 Certificate in Engineering
- Pearson BTEC International Level 2 Extended Certificate in Engineering
- Pearson BTEC International Level 2 Extended Certificate in Mechatronics
- Pearson BTEC International Level 2 Extended Certificate in Vehicle Technology
- Pearson BTEC International Level 2 Diploma in Engineering
- Pearson BTEC International Level 2 Diploma in Mechatronics
- Pearson BTEC International Level 2 Diploma in Vehicle Technology.

### Pearson BTEC International Level 2 Award in Engineering

### Mandatory units

There are two mandatory units, which include one unit assessed internally and one unit assessed through a Pearson Set Assignment. Learners must complete and achieve a Pass or above in all mandatory units.

### Optional units

Learners must complete 60 GLH of optional units.

| **Pearson BTEC International Level 2 Award in Engineering** | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **Optional units – learners complete at least 60 GLH** | | | | |
| **3** | Investigating an Engineering Product | **30** | **Optional** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Optional** | Set assignment |
| **5** | Mathematics for Engineering Technicians | **30** | **Optional** | Set assignment |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |

| Optional units – learners complete at least 60 GLH *(continued)* | | | | |
|---|---|---|---|---|
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **14** | Fabrication Techniques | **60** | **Optional** | Internal |
| **15** | Engineering Marking Out | **30** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **28** | Automated Systems | **60** | **Optional** | Internal |

### Pearson BTEC International Level 2 Certificate in Engineering

#### Mandatory units

There are three mandatory units, which include one unit assessed internally and two units assessed through Pearson Set Assignments. Learners must complete and achieve a Pass or above in all mandatory units.

#### Optional units

Learners must complete 150 GLH of optional units.

| Pearson BTEC International Level 2 Certificate in Engineering | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **Optional units – learners complete at least 150 GLH** | | | | |
| **4** | Engineering Maintenance | **30** | **Optional** | Set assignment |
| **5** | Mathematics for Engineering Technicians | **30** | **Optional** | Set assignment |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |
| **14** | Fabrication Techniques | **60** | **Optional** | Internal |
| **15** | Engineering Marking Out | **30** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |

| Optional units – learners complete at least 150 GLH *(continued)* | | | | |
|---|---|---|---|---|
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **28** | Automated Systems | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |

### Pearson BTEC International Level 2 Extended Certificate in Engineering

#### Mandatory units

There are four mandatory units, which include one unit assessed internally and three units assessed through Pearson Set Assignments. Learners must complete and achieve a Pass or above in all mandatory units.

#### Optional units

Learners must complete 240 GLH of optional units.

| Pearson BTEC International Level 2 Extended Certificate in Engineering | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Mandatory** | Set assignment |
| **Optional units – learners complete at least 240 GLH** | | | | |
| **5** | Mathematics for Engineering Technicians | **30** | **Optional** | Set assignment |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **11** | Welding | **60** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |
| **14** | Fabrication Techniques | **60** | **Optional** | Internal |
| **15** | Engineering Marking Out | **30** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **18** | Applied Chemistry for Engineers | **30** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |

| Optional units – learners complete at least 240 GLH *(continued)* | | | | |
|---|---|---|---|---|
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **28** | Automated Systems | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |
| **32** | Vehicle Engine Technology | **60** | **Optional** | Internal |

### Pearson BTEC International Level 2 Extended Certificate in Mechatronics

#### Mandatory units

There are six mandatory units, which include three units assessed internally and three units assessed through a Pearson Set Assignment. Learners must complete and achieve a Pass or above in all mandatory units.

#### Optional units

Learners must complete 120 GLH of optional units.

| Pearson BTEC International Level 2 Extended Certificate in Mechatronics | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units Group A – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Mandatory** | Set assignment |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Mandatory** | Internal |
| **28** | Automated Systems | **60** | **Mandatory** | Internal |
| **Optional units Group B – learners complete at least 120 GLH** | | | | |
| **5** | Mathematics for Engineering Technicians | **30** | **Optional** | Set assignment |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **11** | Welding | **60** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |

| Optional units Group B – learners complete at least 120 GLH *(continued)* | | | | |
|---|---|---|---|---|
| **18** | Applied Chemistry for Engineers | **30** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |
| **33** | Vehicle Electrical and Electronic Systems | **60** | **Optional** | Internal |

**Pearson BTEC International Level 2 Extended Certificate in Vehicle Technology**

### Mandatory units

There are four mandatory units, which include one unit assessed internally and three units assessed through Pearson Set Assignments. Learners must complete and achieve a Pass or above in all mandatory units.

### Optional units

Learners must complete 360 GLH of optional units.

The optional units are grouped. Learners must take:

- 180 GLH from Group C.

| Pearson BTEC International Level 2 Extended Certificate in Vehicle Technology | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units Group A – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Mandatory** | Set assignment |
| **Optional units Group B** | | | | |
| **5** | Mathematics for Engineering Technicians | **30** | **Optional** | Set assignment |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **11** | Welding | **60** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **18** | Applied Chemistry for Engineers | **30** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |

| Optional units Group B *(continued)* | | | | |
|---|---|---|---|---|
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **28** | Automated Systems | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |
| **Optional units Group C (vehicle) – learners must complete at least 180 GLH** | | | | |
| **30** | Sustainable Vehicle Power and Structure Design | **60** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |
| **32** | Vehicle Engine Technology | **60** | **Optional** | Internal |
| **33** | Vehicle Electrical and Electronic Systems | **60** | **Optional** | Internal |
| **34** | Hybrid and Electric Vehicles | **60** | **Optional** | Internal |

### Pearson BTEC International Level 2 Diploma in Engineering

#### Mandatory units

There are five mandatory units, which include one unit assessed internally and four units assessed through Pearson Set Assignments. Learners must complete and achieve a Pass or above in all mandatory units.

#### Optional units

Learners must complete 330 GLH of optional units.

| Pearson BTEC International Level 2 Diploma in Engineering | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Mandatory** | Set assignment |
| **5** | Mathematics for Engineering Technicians | **30** | **Mandatory** | Set assignment |
| **Optional units – learners complete at least 330 GLH** | | | | |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **11** | Welding | **60** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |
| **14** | Fabrication Techniques | **60** | **Optional** | Internal |
| **15** | Engineering Marking Out | **30** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **18** | Applied Chemistry for Engineers | **30** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |

| Optional units – learners complete at least 330 GLH *(continued)* | | | | |
|---|---|---|---|---|
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **28** | Automated Systems | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |
| **32** | Vehicle Engine Technology | **60** | **Optional** | Internal |

### Pearson BTEC International Level 2 Diploma in Mechatronics

#### Mandatory units

There are seven mandatory units, which include three units assessed internally and four units assessed through a Pearson Set Assignment. Learners must complete and achieve a Pass or above in all mandatory units.

#### Optional units

Learners must complete 210 GLH of optional units.

The optional units are grouped. Learners must take:

- at least 60 GLH from Group C and at least 30 GLH from Group D.

| Pearson BTEC International Level 2 Diploma in Mechatronics | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units Group A – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Mandatory** | Set assignment |
| **5** | Mathematics for Engineering Technicians | **30** | **Mandatory** | Set assignment |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Mandatory** | Internal |
| **28** | Automated Systems | **60** | **Mandatory** | Internal |
| **Optional units Group B** | | | | |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **11** | Welding | **60** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |

| Optional units Group B *(continued)* | | | | |
|---|---|---|---|---|
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **18** | Applied Chemistry for Engineers | **30** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |
| **33** | Vehicle Electrical and Electronic Systems | **60** | **Optional** | Internal |
| **Optional units Group C – learners complete at least 60 GLH** | | | | |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **Optional units Group D – learners complete at least 30 GLH** | | | | |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |

### Pearson BTEC International Level 2 Diploma in Vehicle Technology

#### Mandatory units

There are five mandatory units, which include one unit assessed internally and four units assessed through a Pearson Set Assignment. Learners must complete and achieve a Pass or above in all mandatory units.

#### Optional units

Learners must complete 330 GLH of optional units.

The optional units are grouped. Learners must take:

- at least 30 GLH from Group B and at least 240 GLH from Group C.

| Pearson BTEC International Level 2 Diploma in Vehicle Technology | | | | |
|---|---|---|---|---|
| **Unit number** | **Unit title** | **GLH** | **Type** | **How assessed** |
| **Mandatory units Group A – learners complete and achieve all units** | | | | |
| **1** | Working Safely and Effectively in Engineering | **30** | **Mandatory** | Internal |
| **2** | Engineering Thinking Skills to Create Solutions | **30** | **Mandatory** | Set assignment |
| **3** | Investigating an Engineering Product | **30** | **Mandatory** | Set assignment |
| **4** | Engineering Maintenance | **30** | **Mandatory** | Set assignment |
| **5** | Mathematics for Engineering Technicians | **30** | **Mandatory** | Set assignment |
| **Optional units Group B – learners complete at least 30 GLH** | | | | |
| **6** | Engineering Materials | **30** | **Optional** | Internal |
| **7** | Engineering Drawing | **60** | **Optional** | Internal |
| **8** | Machining Techniques | **60** | **Optional** | Internal |
| **9** | Engineering Design | **60** | **Optional** | Internal |
| **10** | Engineering Fitting and Assembly | **30** | **Optional** | Internal |
| **11** | Welding | **60** | **Optional** | Internal |
| **12** | Business Improvement Techniques | **30** | **Optional** | Internal |
| **13** | Operations and Maintenance of Mechanical Systems and Components | **60** | **Optional** | Internal |
| **16** | Application of Quality Control and Measurement in Engineering | **60** | **Optional** | Internal |
| **17** | 3D Printing | **60** | **Optional** | Internal |
| **18** | Applied Chemistry for Engineers | **30** | **Optional** | Internal |
| **19** | Data Capture and Interpretation | **60** | **Optional** | Internal |

| Optional units Group B – learners complete at least 30 GLH *(continued)* | | | | |
|---|---|---|---|---|
| **20** | Electrical and Mechanical Science for Engineering | **30** | **Optional** | Internal |
| **21** | Renewable Technologies and Sustainability | **60** | **Optional** | Internal |
| **22** | Electrical and Electronic Circuit Construction and Testing | **60** | **Optional** | Internal |
| **23** | Electronic Devices and Communication Applications | **60** | **Optional** | Internal |
| **24** | Operation and Maintenance of Electrical and Electronic Systems and Components | **60** | **Optional** | Internal |
| **25** | Computer Numerical Control Programming and Machining | **60** | **Optional** | Internal |
| **26** | Robotics | **60** | **Optional** | Internal |
| **27** | General Programming | **60** | **Optional** | Internal |
| **28** | Automated Systems | **60** | **Optional** | Internal |
| **29** | Cyber Security in Engineering | **30** | **Optional** | Internal |
| **Optional units Group C (vehicle) – learners must complete at least 240 GLH** | | | | |
| **30** | Sustainable Vehicle Power and Structure Design | **60** | **Optional** | Internal |
| **31** | Vehicle Maintenance Techniques | **60** | **Optional** | Internal |
| **32** | Vehicle Engine Technology | **60** | **Optional** | Internal |
| **33** | Vehicle Electrical and Electronic Systems | **60** | **Optional** | Internal |
| **34** | Hybrid and Electric Vehicles | **60** | **Optional** | Internal |

### Set assignment units

This is a summary of the type and availability of set assignment units. For more information, see *Section 5 Assessment structure*, and the units and sample assessment materials.

| Unit | Type | Availability |
|---|---|---|
| **Unit 2: Engineering Thinking Skills to Create Solutions** | · An assignment set by Pearson and marked by the centre.<br>· The advised assessment period is 8 hours. | **Two available for each series.** |
| **Unit 3: Investigating an Engineering Product** | · An assignment set by Pearson and marked by the centre.<br>· The advised assessment period is 4 hours. | **Two available for each series.** |
| **Unit 4: Engineering Maintenance** | · An assignment set by Pearson and marked by the centre.<br>· The advised assessment period is 6 hours. | **Two available for each series.** |
| **Unit 5: Mathematics for Engineering Technicians** | · An assignment set by Pearson and marked by the centre.<br>· The advised assessment period is 1 hour. | **Two available for each series.** |

### Employer involvement in assessment and delivery

You are encouraged to give learners opportunities to be involved with employers. For more information, please see *Section 4 Planning your programme*.

# 3 Units

## Understanding your units

The units in this specification set out our expectations of assessment in a way that helps you to prepare your learners for assessment. The units help you to undertake assessment and quality assurance effectively.

Each unit in the specification is set out in a similar way. This section explains how the units work. It is important that all teachers, assessors, internal verifiers and other staff responsible for the programme review this section.

| Section | Explanation |
|---|---|
| **Unit number** | The number is in a sequence in the sector. Numbers may not be sequential for an individual qualification. |
| **Unit title** | This is the formal title that we always use, it appears on certificates. |
| **Level** | All units are at Level 2. |
| **Unit type** | This shows if the unit is internal or assessed using a Pearson Set Assignment. See structure information in *Section 2 Structure* for details. |
| **Guided Learning Hours (GLH)** | Units may have a GLH value of 60 or 30. This indicates the numbers of hours of teaching, directed activity and assessment expected. It also shows the weighting of the unit in the final qualification grade. |
| **Unit in brief** | This is a brief formal statement on the content of the unit that is helpful in understanding its role in the qualification. You can use this in summary documents, brochures, etc. |
| **Unit introduction** | This is written with learners in mind. It indicates why the unit is important, how learning is structured and how it might be applied when they progress to employment or higher education. |
| **Assessment** | For internal set assignment units, this section states whether set assignments are required to be completed. |
| **Learning aims** | These help to define the scope, style and depth of learning of the unit. You can see where learners should be learning standard requirements ('understand') or where they should be actively researching ('investigate'). You can find out more about the verbs we use in the learning aims in *Appendix 2: Glossary of terms used*. |
| **Summary of unit** | This section helps teachers to see at a glance the main content areas given against the learning aims and the structure of the assessment. The content areas and structure of assessment must be covered. The forms of evidence given are suitable to fulfil the requirement. |

| Section | Explanation |
|---|---|
| **Content** | 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 content for the unit or learning aim(s) has been covered. |
| **Assessment criteria** | Each learning aim has Pass and Merit criteria. Each assignment has at least one Distinction criterion.<br>A full glossary of terms used is given in *Appendix 2: Glossary of terms used.* All assessors need to understand our expectations of the terms used.<br>Distinction criteria represent outstanding performance in the unit. Some criteria require learners to draw together learning from across the learning aims. |
| **Essential information for assignments** | This shows the maximum number of assignments that may be used for the unit to allow for effective summative assessment and how the assessment criteria should be used to assess performance.<br>For set assignment units, this section will include any conditions for taking the assignment. |
| **Further information for teachers and assessors** | This section gives you information to support the implementation of assessment. It is important that this is read carefully alongside the assessment criteria, as the information will help with interpretation of the requirements. |
| **Resource requirements** | Any specific resources that you need to be able to teach and assess are listed in this section. For information on support resources, see *Section 10 Resources and support*. |
| **Essential information for assessment decisions** | This section gives guidance on and examples for each learning aim or assignment of the expectations for Pass, Merit and Distinction standard. |
| **Assessment controls** | This section gives details of the rules that learners need to abide by when taking the assessment. |
| **Links to other units and other curriculum subjects** | This section shows you the main relationships between different units and any clear links to other curriculum subjects. This helps you to structure your programme and make best use of available materials and resources. |
| **Employer involvement** | This section gives you information on the units, which can be used to involve learners with employers. This will help you to identify the kind of involvement that is likely to be most successful. |
| **Opportunities to develop transferable employability skills** | This section gives you guidance on how transferable employability skills might be developed in teaching and assessment of the unit. |

## Index of units

This section contains all the units developed for these qualifications. Please refer to *pages 5–6* to check which units are available in all qualifications in the engineering sector.

# Unit 1: Working Safely and Effectively in Engineering

Level: **2**
Unit type: **Internal**
Guided learning hours: **30**

## Unit in brief

Learners will consider health and safety procedures and responsibilities and prepare for and carry out an engineering work activity safely.

## Unit introduction

The ability to work safely and effectively in an engineering environment is essential for your own wellbeing and that of others. This unit will help you to understand health and safety requirements and to know how to prepare for and carry out an engineering work activity safely and effectively in a workshop environment. This way, you can enjoy all the challenges that engineering activities can offer without undue fear for your own safety or for that of others.

The initial focus of the unit is to understand safe procedures in an engineering workplace. In the event of an incident, it is essential that you know how to respond. This unit will also take you through the important health and safety legislation and regulations that you need to know when you go into an engineering workplace, and the related responsibilities of an employer and employees.

You will then consider hazards and risks and the most appropriate personal protective equipment (PPE) to use when undertaking particular engineering work activities. Finally, you will learn how to safely prepare a workshop environment and carry out engineering work activities safely and effectively.

The knowledge and understanding gained through completing this unit will be put to good use in other areas of engineering study and working life.

## Learning aims

In this unit you will:

**A** Understand safe procedures and health and safety responsibilities in an engineering workplace

**B** Know how to undertake an engineering work activity safely and effectively.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Understand safe procedures and health and safety responsibilities in an engineering workplace | **A1** Accident and emergency procedures<br>**A2** Health and safety responsibilities in an engineering workplace | A report, based on a given health and safety incident in an engineering workplace, detailing the use of accident procedures and the health and safety responsibilities of the employer and employees under the requirements of law and regulations that apply. Diagrams/images may be included. |
| **B** Know how to undertake an engineering work activity safely and effectively | **B1** Hazards, risks and risk assessment<br>**B2** Personal protective equipment (PPE)<br>**B3** Engineering work activity | A practical activity involving the safe preparation and carrying out of an engineering work activity.<br>The assessment evidence will include the finished item and a small portfolio with safety notes, annotated photographs, learner observation records/witness statements and a written report justifying the procedures used. |

## Content

### Learning aim A: Understand safe procedures and health and safety responsibilities in an engineering workplace

**A1 Accident and emergency procedures**

Accident and emergency procedures to be followed in response to an incident in an engineering workplace, including:

- identification of appropriately qualified persons, e.g. supervisor, first aider, fire warden
- procedures in the event of an accident such as a person injuring themselves while using an engineering process, e.g. assessing the situation, contacting an emergency service, planning assistance for those affected, location of first-aid facilities, supporting a first-aider, handover to the emergency service, reporting and recording the accident
- procedures in the event of an emergency such as a fire due to an engineering equipment malfunction, e.g. sounding of the emergency alarm, evacuating using the correct escape route, staying at the established assembly point, accounting for all persons, supporting the fire warden to use a fire extinguisher if safe to do so, handover to the emergency services, reporting and recording the emergency.

**A2 Health and safety responsibilities in an engineering workplace**

Health and safety responsibilities of the employer and employees in an engineering workplace, including:

- responsibilities under the requirements of the current Health and Safety at Work legislation or international equivalent, e.g. duty of care, assessing hazards and controlling risks, providing training on risks and how to deal with them, caring for self and others, cooperation, using control measures, not interfering with or misusing equipment
- responsibilities under the requirements of the current Manual Handling Operations Regulations (MHOR) or international equivalent, e.g. removing the need for manual handling, assessing the risk of injury when manual handling is required, controlling and reducing the risk of injury, training in the use of techniques, correct use of techniques
- responsibilities under the requirements of the current personal protective equipment (PPE) at Work Regulations or international equivalent, e.g. only using if the risk cannot be controlled in any other way, assessing suitable PPE given the hazard, supplying PPE, instructions/training, correct use, maintenance and storage
- responsibilities under the requirements of the current Control of Substances Hazardous to Health Regulations (COSHH) or international equivalent, e.g. identifying harmful substances, assessing risks of exposure, providing safety data sheets, using and maintaining control measures/equipment, providing and attending training/instruction/information
- correct storage responsibilities under the requirements of the current Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) or international equivalent, e.g. having and maintaining an accident book, identifying reportable incidents, submission of reports by responsible persons, timely reporting

- consequences of employers and employees not conforming to the requirements of the current and relevant legislation and regulations, including:
  - increased risk of short-term or long-term injury or ill health, e.g. to persons and/or groups of persons
  - loss of reputation, e.g. for a company and/or a person
  - financial costs, e.g. efficiency losses, compensation
  - legal implications, e.g. prison terms, fines.

## Learning aim B: Know how to undertake an engineering work activity safely and effectively

### B1 Hazards, risks and risk assessment

Hazards in the engineering workplace, including:

- types, e.g. moving parts or processes, unshielded or hot processes, sharp objects or tools and equipment, material ejection, electricity, uneven surfaces or confined spaces, dust and fumes, contaminants, fire, working at height, stored energy systems, volatile or toxic materials, handling and transporting items.

Risks in the engineering workplace, including:

- to the body, e.g. inhalation, absorption, ingestion or injection of gases, liquids or chemicals, cuts and bruises, slips and trips, burns
- during an engineering work activity, e.g. not following safe working practices and procedures, spillages of oil and chemicals, slips and trips, accidental breakages of tools or equipment, uncontrolled processes.

Steps to complete a risk assessment, including:

- identifying the hazard/s
- deciding who might be harmed
- evaluating the risk/s and determining suitable control measure/s
- recording and implementing findings
- reviewing and updating the assessment.

### B2 Personal protective equipment (PPE)

Selecting and knowing how to use personal protective equipment for an engineering work activity, including:

- clothing for general workshop activities, e.g. overalls, leather apron
- footwear for general workshop activities, e.g. resistant to chemicals, toe capped
- eye protection for a range of machinery and equipment, e.g. glasses, goggles, shield
- skin care, e.g. barrier creams, gloves
- breathing protection, e.g. masks, respirators
- hearing protection, e.g. ear plugs, ear defenders.

### B3 Engineering work activity

Safely preparing a workshop environment before an engineering work activity, including:

- types of engineering work activity (e.g. machining/manufacturing a product or component, servicing/maintenance of plant or equipment, construction/testing of circuits, installing/commissioning equipment or systems)
- ensuring that the work area is free from hazards
- using correct personal protective equipment and hygiene procedures
- obtaining and understanding engineering drawings and/or work instructions
- obtaining suitable materials, tools and equipment and carrying out checks to ensure that they are in a safe and usable condition
- using suitable lifting and carrying techniques.

Safely and effectively carrying out an engineering work activity in a workshop environment, including:

- working with others (e.g. getting authorisation to carry out work, knowing when to work independently and when to ask for assistance, requesting information, documentation, materials, tools and equipment)
- implementing safety procedures
- using tools and equipment safely and only for the purpose intended
- completing all tasks safely and filling in documentation (if required)
- demonstrating good housekeeping by maintaining a tidy and clean work area
- taking measures to protect others from harm that might result from an engineering work activity
- carrying out checks to ensure that tools and equipment are in a safe and usable condition after task completion
- returning engineering drawings and/or work instructions and tools and equipment back to storage after task completion
- correctly disposing of unusable tools and equipment, components and waste materials (e.g. oil, soiled rags, swarf/offcuts) after task completion
- reporting issues or suggestions (e.g. machine, tooling or quality problems, possible improvements in work methods).

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Understand safe procedures and health and safety responsibilities in an engineering workplace** | | **A.D1** Evaluate the use of accident procedures and consequences of employers and employees not conforming to health and safety laws/regulation. |
| **A.P1** Describe the use of accident procedures in an engineering workplace.<br>**A.P2** Describe employer and employee responsibilities to comply with health and safety law/regulations. | **A.M1** Explain the use of accident procedures in given scenarios where employer and employee have not complied with health and safety law/regulations. | |
| **Learning aim B: Know how to undertake an engineering work activity safely and effectively** | | **B.D2** Justify procedures used to prepare for and carry out an engineering work activity safely, independently and effectively. |
| **B.P3** Identify risks for a given engineering activity.<br>**B.P4** Select correct personal protective equipment for a given engineering work activity.<br>**B.P5** Prepare for and carry out an engineering work activity safely with some assistance. | **B.M2** Prepare for and carry out an engineering work activity safely, independently and effectively. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.P5, B.M2, B.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- computers and the internet to enable learners to research current law and regulations relating to health and safety in the engineering workplace
- a suitable blank template for risk assessments on an engineering work activity in a workshop environment
- a workshop environment and the range of tools and equipment required to carry out engineering work activities.

## Essential information for assessment decisions

The assessment activity for learning aim A must include the details of a simulated health and safety incident in an engineering workplace. The scenario will provide full details of an accident (for example, a serious injury to an employee using a lathe where there was no guarding on the machine, no risk assessment for the activity and the employee did not use the PPE supplied) and the procedures used immediately after such an accident (for example, emergency services contacted immediately but first-aid facilities difficult to find).

## Learning aim A

**For Distinction standard**, learners will:

- Produce evidence that demonstrates that they can evaluate a given health and safety incident in an engineering workplace.
- Accurately identify and consider both the correct and incorrect use of accident procedures for a given health and safety incident and justify the procedures that should have been used in a contextual manner, for example by considering the extent of the employee's injury.
- Accurately identify and consider the legislation and each of the regulations that apply to the given health and safety incident and what caused the incident, and assess to what extent both the employer and employee(s) have not conformed to the necessary requirements, for example by taking into account the provision of a risk assessment, training and control measures and whether the employee used the correct equipment in the right way.
- Identify and consider the possible consequences of the employer and employee not conforming to the requirements of the legislation and regulations that apply, for example by assessing what the long-term health impact could be for the employee that was injured, what could happen due to a loss of reputation, what the financial costs might be and the possible legal implications.

**For Merit standard**, learners will:

- Produce evidence that demonstrates that they can explain a given health and safety incident in an engineering workplace.
- Consider why accident procedures were used for a given health and safety incident, for example by explaining, in a contextual manner, why all the procedures were followed and the reasons they were done in a specific sequence.

- Accurately identify and consider the legislation and each of the regulations that apply to the given health and safety incident and explain what the employer and employee didn't do that caused the incident, for example the employer not assessing specific hazards and controlling risks in the right way and the employee not using the required control measures.

**For Pass standard**, learners will:

- Produce evidence that demonstrates that they can describe accident procedures and the health and safety responsibilities of the employer and employees in an engineering workplace.
- Write about the accident procedures used for a health and safety incident, for example by describing how the procedures listed in the content for learning aim A will be used if an employee is seriously injured when using a machine.
- Write about the legislation and some of the regulations that apply to the given health and safety incident and what the health and safety responsibilities of the employer and employees are, for example by describing duty of care and caring for self and others.

### Learning aim B

The assessment activity for learning aim B must include full details of the engineering work activity to be completed. The engineering work activity must take place in a workshop environment and learners should be provided with an engineering drawing. Examples of suitable engineering work activities include (but are not limited to):

- drilling and reaming a hole through plate
- milling a smooth face on square bar
- turning a smooth face on round bar
- welding a joint to attach two plates.

**For Distinction standard**, learners will:

- Produce a suitable risk assessment for the engineering work activity. This must cover the full range of hazards accurately, who might be harmed, the specific risks and suitable control measures.
- Select the correct personal protective equipment to be used for an engineering work activity. They must accurately select all of the most suitable PPE that is required for the specific engineering work activity.
- Prepare for and carry out an engineering work activity safely, independently and effectively. They will complete all of the 'preparing' and 'carrying out' activities listed in the content for learning aim B (B3). Any assistance from the tutor must be strictly limited to verbal confirmation that the learner is carrying out the engineering work activity in a safe manner.
- Justify the procedures used to prepare for and carry out an engineering work activity. They will justify why all of the tasks completed to prepare for and carry out an engineering work activity were needed to ensure the engineering work activity was carried out in a safe and effective manner, for example why good housekeeping is required, why checks are important to ensure that tools and equipment are in a safe and usable condition after task completion and why any quality problems need to be reported. The justification will be contextualised to the specific engineering work activity.

**For Merit standard**, learners will:

- Produce a suitable risk assessment for the engineering work activity. This must cover the full range of hazards accurately, who might be harmed, the specific risks and suitable control measures.
- Select the correct personal protective equipment to be used for an engineering work activity. They must accurately select all of the most suitable PPE that is required for the specific engineering work activity.
- Prepare for and carry out an engineering work activity safely, independently and effectively. They will complete all of the 'preparing' and 'carrying out' activities listed in the content for learning aim B (B3). Any assistance from the tutor must be strictly limited to verbal confirmation that the learner is carrying out the engineering work activity in a safe manner.

**For Pass standard**, learners will:

- Produce a risk assessment for the engineering work activity. As a minimum, this must cover the most obvious hazards and suitable control measures accurately, for example flying swarf and guarding.
- Select the correct personal protective equipment to be used for an engineering work activity. As a minimum, they must accurately select the most obvious PPE that is required for the engineering work activity, such as a leather apron and mask if welding.
- Prepare for and carry out an engineering work activity safely with some assistance. They will complete all of the 'preparing' and 'carrying out' activities listed in the content for learning aim B. They will ask questions and seek and receive clarification while undertaking the engineering work activity, but the tutor will have to actively intervene because there is a risk that the learner will carry out the engineering work activity in an unsafe manner, for example by starting a drill with the key still in the chuck.

## Links to other units and curriculum subjects

This unit underpins all other units.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest or partner speakers from industry, to discuss the importance of health and safety in engineering with contextualised examples. A range of industrial case studies would aid the delivery of the unit and would also allow learners to consider the full range of health and safety issues and incidents
- visits to industrial workshops to encounter real-life working practices and health and safety procedures
- work experience, which will allow learners to become much more familiar with industrial engineering environments and the way they are set up to prevent health and safety issues and incidents.

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## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in:

### Problem solving

- Selecting safe and appropriate approaches to carry out engineering work activities.

### Managing information

- Interpreting health and safety incidents.

### Self-management and development

- Safely and effectively self-managing the preparation and carrying out of engineering work activities.

# Unit 2: Engineering Thinking Skills to Create Solutions

Level: **2**

Unit type: **Pearson Set Assignment**

Guided learning hours: **30**

## Unit in brief

Learners will develop a prototype to solve an engineering challenge and review the performance of the prototype and the approaches and behaviours they applied.

## Unit introduction

The primary role of an engineer is to “collaborate with others to make new things that work and make existing things work better”. Effective and successful engineers tend to have one thing in common; how they think about and solve problems.

In this unit, you will consider how a range of approaches and behaviours underpin and support the way engineers work. You will look at how these ways of thinking are applied when developing (design, make, test and improve) a prototype solution to an engineering challenge.

Adopting engineering perspectives and applying these in your work is essential to anyone pursuing a career in engineering. This unit will help prepare you for employment in any engineering sector, an apprenticeship, or for progression into further study.

## Assessment

This unit has a Pearson Set Assignment. Learners must complete a Pearson Set Assignment Brief.

## Learning aims

In this unit you will:

**A** Develop a prototype to solve an engineering challenge

**B** Review the performance of a prototype to solve an engineering challenge and the approaches and behaviours that were applied.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Develop a prototype to solve an engineering challenge | **A1** Engineering principles<br>**A2** Iterative approach to problem solving<br>**A3** Approaches to facilitate problem solving<br>**A4** Prototyping<br>**A5** Behaviours | This unit is assessed through a Pearson Set Assignment. |
| **B** Review the performance of a prototype to solve an engineering challenge and the approaches and behaviours that were applied | **B1** Peer review<br>**B2** Reviewing the performance of the finished prototype solution<br>**B3** Reviewing the approaches used to solve problems<br>**B4** Reviewing behaviours | |


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# Content

## Learning aim A: Develop a prototype to solve an engineering challenge

### A1 Engineering principles

Basic calculations and application of engineering key principles when developing prototypes:

- force including friction, weight, tension and compression
- physical properties of materials including mass, density, insulators/conductors
- mechanical properties of materials including elasticity, tensile/compressive strength
- magnetism including attraction and repulsion
- electrical/electronic (direct current) including current, voltage, resistance, continuity, circuit components, e.g. switches, resistors, light emitting diodes
- applications of mechanical advantage including levers and pulleys
- motion of a body in a straight line including velocity and distance
- conservation of energy/momentum
- Newton's Laws of motion.

### A2 Iterative approach to problem solving

The steps required for iterative problem solving:

- describe the problem
- describe the results required, e.g. goals, success criteria
- gather information, e.g. availability of resources, limitations, constraints
- think of ideas in terms of form and approach that could solve the problem
- select the solution most likely to work
- safely implement solution selected
- evaluate results
- suggest improvements
- repeat until success criteria are achieved.

### A3 Approaches to facilitate problem solving

Approaches used to help facilitate effective problem solving:

- keeping records, e.g. notes, logbooks, photo diaries
- methodical and structured approach, e.g. following processes, carrying out activities in a logical sequence
- presentation of information, e.g. diagrams, tables, plans, procedures, lists, charts
- informal pictorial sketching techniques that convey information/understanding, e.g. 3D sketches, 2D sketches, annotation, dimensions
- using standard forms, e.g. test record sheets, feedback forms
- making the best use of available resources, e.g. using materials efficiently, exploiting key material characteristics
- adapting, e.g. repurposing components

- creative problem solving or idea generation in terms of form and approach, e.g. mind mapping, deconstruction/breaking a problem down into smaller parts, thumbnail sketching, substitution, combination, adaptation, modification, put to another use, eliminate, reverse
- visualising, e.g. sketching, model making, mind maps, spider diagrams, fish bone diagrams, flow charts
- systems thinking, e.g. identifying root causes that will have most impact
- improving, e.g. reducing waste/mass, increasing distance travelled/velocity.

### A4 Prototyping

Safe use of appropriate materials and making skills required to make a functional prototype:

- materials, e.g. paper, card, wood, polymers, glue, tape, string, wire, nails, straws, springs, elastic-bands
- making skills, e.g. measuring, marking out, cutting, joining.

Safe testing and experimentation to inform the design process and make improvements:

- testing of individual components or partial sub-assemblies
- testing of sample materials and construction techniques.

Safe testing of a finished functional prototype:

- measuring and setting initial test parameters, e.g. distance, mass, volume, angle
- measuring key performance characteristics, e.g. time, distance, mass.

### A5 Behaviours

- Professional behaviours, e.g. following rules of conduct, politeness.
- Engineering behaviours to include:
    - curiosity, e.g. investigating how things work
    - open-mindedness, e.g. considering unfamiliar situations
    - resilience, e.g. not giving up
    - resourcefulness, e.g. making the best of what is available, efficient use of resources
    - peer collaboration, e.g. communicating, presenting and demonstrating.

## Learning aim B: Review the performance of a prototype to solve an engineering challenge and the approaches and behaviours that were applied

### B1 Peer review

- Types of review including performance of the finished solution against the objectives of the engineering challenge.
- Methods to gather feedback from peers, e.g. questionnaire, conversation, form.
- Recording feedback, e.g. paper, digital, audio-visual.

### B2 Reviewing the performance of the finished prototype solution

- Performance of the finished solution against the success criteria of the engineering challenge, e.g. distance travelled, mass supported.
- Application of engineering principles underpinning the solution, e.g. forces applied, mechanical advantage.
- Self-reflection on the effectiveness of the finished prototype solution.

**B3 Reviewing the approaches used to solve problems**

- Iterative approach.
- Approaches to facilitate problem solving, e.g. thumbnail sketching, methodical approach.
- Self-reflection on the effectiveness of the approaches to problem solving.

**B4 Reviewing behaviours**

- Professional behaviours, e.g. politeness, following workshop rules.
- Engineering behaviours, e.g. curiosity, open-mindedness, resilience, resourcefulness, collaboration and self-reflection.
- Self-reflection on the effectiveness of the behaviours applied.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Develop a prototype to solve an engineering challenge** | | **A.D1** Develop a prototype solution safely and effectively using different ideas and problem-solving approaches iteratively, and appropriate practical skills consistently, comprehensively demonstrating the finished solution. |
| **A.P1** Produce a design idea for a prototype solution using at least one problem-solving approach.<br>**A.P2** Create a prototype solution using practical skills safely.<br>**A.P3** Complete a basic demonstration of the finished prototype solution. | **A.M1** Develop a prototype solution safely using different ideas, problem-solving approaches, and mostly appropriate practical skills, soundly demonstrating the finished solution. | |
| **Learning aim B: Review the performance of a prototype to solve an engineering challenge and the approaches and behaviours that were applied** | | **B.D2** Evaluate, using feedback from peers appropriately, how well the finished prototype solved the engineering challenge, and the effectiveness of the behaviours and approaches that were applied. |
| **B.P4** Collect feedback from peers on how well the prototype solution solved the engineering challenge.<br>**B.P5** Describe how well the prototype solution solved the engineering challenge.<br>**B.P6** Describe the approach(es) and behaviour(s) that were applied when solving the engineering challenge. | **B.M2** Explain, using feedback from peers, how well the finished prototype solution solved the engineering challenge and the effectiveness of the behaviours and approaches that were applied. | |

## Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners.

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to a classroom or workshop with sufficient space for building and testing prototypes.

A range of basic hand tools and modelling material will be required as indicated in the unit content.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Use at least two problem-solving approaches effectively when producing at least two design ideas detailing the form and approach. For example:
  - using thumbnail sketching to generate a range of design ideas
  - following all the steps of an iterative problem-solving approach methodically maintaining well-structured and detailed notes to record the problem-solving process. Learners will use at least one design iteration to develop (design, make, test and improve) the prototype solution. This will have significant impact on the design and/or performance and be clearly documented. This might involve improving:
    - the design of a single component, sub-assembly or joining method after some initial experimentation, e.g. increasing the strength of a taped joint by using hot glue instead
    - performance of the complete prototype solution, e.g. by changing variables such as the length, position or tension of a spring.
- Learners will use safe and appropriate practical skills consistently when developing the prototype solution. For example, consistent and appropriate:
  - use of tools and equipment, e.g. using scissors to cut compliant materials such as paper or card but not attempting to use them to cut wood or metal wire
  - housekeeping skills, e.g. maintaining a tidy work area and storing tools and equipment appropriately
  - use of materials, e.g. minimising waste when nesting components cut from card
  - measurement and marking out, e.g. using a ruler and pencil accurately for marking out a wooden component for cutting.
- Learners will give a comprehensive and safe demonstration of their solution. For example, a comprehensive demonstration will include:
  - learners being fully prepared to demonstrate their solution at a given time
  - clear explanations of operation e.g. will link design and operation to relevant key engineering principles.

**For Merit standard**, learners will:

- Use at least two problem-solving approaches when producing at least two design ideas. One of these may not have been fully effective, for example:
  - using thumbnail sketching with poor annotation or difficult to interpret sketches
  - use of iteration, if present, may have a negligible impact on the design and/or performance of the solution and/or be poorly documented, e.g. making colour changes, adding decorative effects.

- Learners will use safe and mostly appropriate practical skills when creating the prototype solution. For example, mostly appropriate:
  - use of tools and equipment. This means that occasionally tools may be inappropriate for the task, e.g. using scissors instead of combination pliers or side cutters to cut metal wire
  - housekeeping skills. This means that occasionally good housekeeping may not be maintained, e.g. having an untidy workspace
  - measurement and marking out. This means that occasionally marking out or measurement is incorrect, e.g. cutting a component too short.
- Learners will give a sound and safe demonstration of their solution. For example, a sound demonstration will include:
  - learners being prepared to demonstrate their solution at a given time, e.g. learners may need prompting and need a little extra time to get organised
  - explanations of operation will be clear but may lack detail, e.g. they may not include relevant engineering principles.

**For Pass standard**, learners will:

- Use at least one problem-solving approach when producing at least one design idea. These may not have been fully effective, for example:
  - using thumbnail sketching with poor annotation and difficult to interpret sketches
  - notes recording the problem-solving process lack detail or appropriate structure.
- Learners will use safe, but sometimes inappropriate practical skills when creating the prototype solution. For example:
  - tools may be inappropriate for the task, e.g. using scissors instead of combination pliers or side cutters to cut metal wire
  - housekeeping may be inappropriate, e.g. having an untidy workspace
  - marking out or measurement may be inappropriate, e.g. cutting a component too short.
- Learners will give a basic and safe demonstration of their solution. For example, a basic demonstration will include:
  - learners not being prepared for the demonstration of their solution at a given time, e.g. they may miss their place and/or need significant additional time to prepare
  - explanations of design and operation may be unclear, lack detail or be incomplete, e.g. they do not cover the operation of the solution fully.

## Learning aim B

**For Distinction standard**, learners will:

- Collect and record feedback from peers effectively, e.g. use a pre-prepared questionnaire and allowing time during or just after the demonstration for this to be completed.
- Provide a detailed evaluation of performance in key areas and suggest improvements that increase performance. Include considerations of any key issues identified in a review of peer feedback. For example, discussing how low speed was identified in both self-reflection and peer review as a key performance area requiring improvement, friction between components was identified as the root cause and design changes and lubrication that will give improved performance.

- Provide a detailed evaluation of at least two approaches used in problem solving and suggest improvements to their application that would make them more effective. For example, discuss how thumbnail sketching was used to generate several ideas, the importance of getting ideas down on paper quickly and how practising quick sketching techniques will improve application of this approach.
- Provide a detailed evaluation of at least two behaviours used in problem solving and suggest improvements to their application that would make them more effective. For example, discuss the role that resilience played when an idea failed to work, the importance of not giving up easily and ways of building up resilience by keeping a positive mental attitude.

**For Merit standard**, learners will:

- Collect and record feedback from peers, e.g. note down some comments during or just after the demonstration.
- Provide a detailed explanation of performance in key areas and suggest improvements that increase performance. Include considerations of any key issues identified in a review of peer feedback. For example, discussing how low speed was identified in both self-reflection and peer review as a key performance area requiring improvement and friction between components was identified as the root cause.
- Provide an explanation of at least two approaches used in problem solving. For example, discuss how thumbnail sketching was used to generate several ideas the importance of getting ideas down on paper quickly.
- Provide an explanation of at least two behaviours used in problem solving. For example, discuss the role that resilience played when an idea failed to work and the importance of not giving up easily.

**For Pass standard**, learners will:

- Collect feedback from peers, e.g. note down some comments from memory after the demonstration.
- Provide a description of performance in key areas and suggest improvements that increase performance. Include considerations of any issues mentioned in peer feedback. For example, discussing how low speed was identified as a performance area requiring improvement.
- Provide a description of at least two approaches used in problem solving. For example, discuss how thumbnail sketching was used to generate several ideas.
- Provide a description of at least two behaviours used in problem solving. For example, discuss the role that resilience played when an idea failed to work.

## Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner work. This may mean that learners should be supervised.

Resources: all learners should have access to the same types of resource to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 6: Engineering Materials
- Unit 8: Machining Techniques
- Unit 10: Engineering Fitting and Assembly
- Unit 13: Operations and Maintenance of Mechanical Systems and Components
- Unit 16: Application of Quality Control and Measurement in Engineering
- Unit 20: Electrical and Mechanical Science for Engineering
- Unit 23: Electronic Devices and Communication Applications
- Unit 28: Automated Systems
- Unit 32: Vehicle Engine Technology.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers
- technical workshops involving staff from local engineering organisations with commercial and quality systems expertise
- contribution of ideas to unit assignment/project materials.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

- conducting thorough exploration of given themes and topics
- producing formal documentation to present findings from investigations into given topics or themes
- taking part in prototype design and production, which will enable them to investigate factors associated with engineering activities.

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# Unit 3: Investigating an Engineering Product

Level: **2**
Unit type: **Pearson Set Assignment**
Guided learning hours: **30**

## Unit in brief

Learners will investigate the selection of specific materials and processes used to manufacture the component parts of engineering products.

## Unit introduction

Did you know that similar engineering products can look and operate very differently if the materials and manufacturing processes used to make them are altered? Think about a simple ceiling fan blade – one that is formed from a metal is likely to perform very differently to one that is moulded from a polymer.

The materials that are used in an engineering product are not selected at random. From the thousands of options available, materials are chosen on the basis of their specific properties and whether they match the purpose and function of the component parts that make up the engineering product.

The processes that are used to manufacture an engineering product are also chosen carefully. When an engineering product is manufactured, particular processes are used so that the component parts are accurate, have the correct features, can be made quickly and are able to fulfil their purpose and function.

In this unit, you will investigate the component parts of engineering products to learn about the materials and processes that were used to manufacture them. You will explore why these materials were used instead of others that might also have been appropriate. You will also consider the impact of scales of production on material selection.

## Assessment

This unit has a Pearson Set Assignment. Learners must complete a Pearson Set Assignment Brief.

## Learning aims

In this unit you will:

**A** Explore the selection of specific materials used in the component parts of an engineering product

**B** Explore the selection of specific processes used to manufacture the component parts of an engineering product.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Explore the selection of specific materials used in the component parts of an engineering product | **A1** Metals and alloys<br>**A2** Polymers<br>**A3** Composites<br>**A4** Properties of materials | This unit is assessed through a Pearson Set Assignment. |
| **B** Explore the selection of specific processes used to manufacture the component parts of an engineering product | **B1** Machining<br>**B2** Shaping and manipulation<br>**B3** Casting and moulding<br>**B4** Joining<br>**B5** Scales of production | |

# Content

## Learning aim A: Explore the selection of specific materials used in the component parts of an engineering product

### A1 Metals and alloys

Material properties and reasons for the selection and application of the following types of ferrous metals, non-ferrous metals and alloys in the component parts of a range of engineering products.

- Ferrous metals – low carbon steel, medium carbon steel, high carbon steel, cast iron, wrought iron.
- Non-ferrous metals – aluminium, copper, zinc, tin, magnesium, titanium, lead, nickel, chromium.
- Alloys – stainless steel, duralumin, brass, bronze.

### A2 Polymers

Material properties and reasons for the selection and application of the following types of thermoplastics, thermosetting polymers and elastomers in the component parts of a range of engineering products.

- Thermoplastics – acrylic, polyvinyl chloride (PVC), polyethylene (PET, LDPE, HDPE), polystyrene, polypropylene (PP), polytetrafluoroethylene (PTFE), nylon, polycarbonate, acrylonitrile butadiene styrene (ABS), polyurethane.
- Thermosetting polymers – formica, melamine resin, urea formaldehyde, epoxy resin, polyester resin.
- Elastomers – vulcanised rubber, neoprene, silicone.

### A3 Composites

Material properties and reasons for the selection and application of the following types of composites in the component parts of a range of engineering products.

- Composites – glass reinforced polymer (GRP), carbon fibre, aramid fibre.

### A4 Properties of materials

- Material properties including:
  - physical – mass, density, melting point, thermal conductivity, electrical conductivity, magnetism, opacity, translucence, transparency
  - mechanical – tensile strength, compressive strength, hardness, toughness, brittleness, malleability, ductility, Young’s modulus, stiffness
  - chemical and durability – corrosion resistance, solvent resistance, resistance to environmental degradation, wear resistance.

## Learning aim B: Explore the selection of specific processes used to manufacture the component parts of an engineering product

### B1 Machining

Key features and reasons for the selection and application of the following types of machining processes when manufacturing the component parts of a range of engineering products.

- Milling – drilling/centre drilling, end milling, slot milling, counterboring, countersinking, boring, tapping, profile cutting, serrations, indexed forms, gear cutting.
- Turning – drilling/centre drilling, parallel turning, taper turning, facing off, screw cutting, counterboring, countersinking, chamfering, boring, parting off, knurling.

- Drilling – drilling/centre drilling, counterboring, countersinking, boring, tapping, reaming.

**B2 Shaping and manipulation**

Key features and reasons for the selection and application of the following types of shaping and manipulation processes when manufacturing the component parts of a range of engineering products.

- Shaping and manipulation – bending, folding, press forming, drawing, punching, stamping, shearing, forging (hot, cold), extrusion, laser cutting.

**B3 Casting and moulding**

Key features and reasons for the selection and application of the following types of casting and moulding processes when manufacturing the component parts of a range of engineering products.

- Casting – sand, die.
- Moulding – injection, blow, rotational, vacuum forming, lay-up, powder metallurgy.

**B4 Joining**

Key features and reasons for the selection and application of the following types of joining processes when manufacturing the component parts of a range of engineering products.

- Joining – welding (MIG, TIG, spot), brazing, soldering, bonding/adhesion, fastenings (nuts and bolts, screws, rivets).

**B5 Scales of production**

The key features of different scales of production when manufacturing the component parts of a range of engineering products:

  - prototype and one-off
  - batch
  - mass
  - continuous.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Explore the selection of specific materials used in the component parts of an engineering product** | | **A.D1** Evaluate the suitability of the materials used in two component parts of an engineering product and propose alternatives. |
| **A.P1** Identify the materials used in two component parts of an engineering product.<br>**A.P2** Describe the properties of the materials used in two component parts of an engineering product. | **A.M1** Explain reasons for the selection and application of the materials used in two component parts of an engineering product. | |
| **Learning aim B: Explore the selection of specific processes used to manufacture the component parts of an engineering product** | | **B.D2** Evaluate the suitability of the processes used to manufacture two component parts of an engineering product and propose alternatives. |
| **B.P3** Identify the processes used to manufacture two component parts of an engineering product.<br>**B.P4** Describe the processes used to manufacture two component parts of an engineering product. | **B.M2** Explain reasons for the selection and application of the processes used to manufacture two component parts of an engineering product. | |

## Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners.

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- physical examples of a range of engineering products with at least two component parts; the component parts should be made from different materials and manufactured using different processes.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Evaluate whether the specific materials used in the two component parts of an engineering product are the most suitable, by comparing the materials used with other appropriate and specific alternative materials that could have been used. They will provide comparisons that give reasons why the specific alternative materials are also suitable and will justify their choices by explicitly linking the purpose and function of both of the component parts to the favourable properties of both of the specific alternative materials chosen.
- Complete their assessment response with a conclusion that provides justified reasons for the specific materials they would actually choose for both of the component parts.

**For Merit standard**, learners will:

- Accurately identify the specific materials that have been used in the two component parts of an engineering product, using terminology such as 'low carbon steel' or 'high density polyethylene'.
- Accurately explain why the specific materials have been used in the two component parts of an engineering product, by providing contextual reasons that consider the overall engineering product in use and the properties of the materials. They will provide reasons that explicitly link the purpose and function of both of the component parts to the favourable properties of both of the materials used.

**For Pass standard**, learners will:

- Identify suitable materials that could be used in the two component parts of an engineering product, but they may be referred to in a generic manner and may not be the materials actually used. For example, the learner may identify the material used for the first component part as 'steel' when the material actually used is low carbon steel, or may identify the material used for the second component part as 'PP' when the material actually used is PVC.
- Describe most of the properties of the materials used in the two component parts of an engineering product, but some of the properties may not be described accurately and some of them may not be entirely relevant. For example, the learner may use some terms that are more related to stiffness when describing hardness or may accurately describe corrosion resistance as a material property when the component will be used in a product/an environment where it is unlikely to corrode.

### Learning aim B

**For Distinction standard**, learners will:

- Evaluate whether the specific processes used to manufacture the two component parts of an engineering product are the most suitable, by comparing the processes used with other appropriate and specific alternative processes that could have been used. They will provide comparisons that give reasons why the specific alternative processes are also suitable and will justify their choices by explicitly referring to details such as the materials, features, purpose and function of each component part and the scale of production required for each component part.
- Complete their assessment response with a conclusion that provides justified reasons for the specific processes they would actually choose to manufacture both of the component parts.

**For Merit standard**, learners will:

- Accurately identify the specific processes that have been used to manufacture the two component parts of an engineering product, using appropriate terminology such as 'MIG welding' or 'slot milling'.
- Accurately explain why the specific processes have been used to manufacture the two component parts of an engineering product, by providing contextual reasons that explicitly refer to details such as the materials, features, purpose and function of each component part and the scale of production required for each component part. For example, the learner may explain why a component part would be hot forged if it needs to be impact resistant, or why a component part would be end and slot milled if the scale of production is small.

**For Pass standard**, learners will:

- Identify suitable processes that could be used to manufacture the two component parts of an engineering product, but they may be referred to in a generic manner and may not be the processes actually used given the scale of production required. For example, the learner may identify a process used for the first component part as 'machine cutting' when the specific process actually used is turning, or may identify a process used for the second component part as 'moulding' when the process actually used is injection moulding.
- Use suitable text and diagrams to describe most of the key features of the processes used to manufacture two component parts of an engineering product, but some of the processes may not be described accurately and some of them may not be entirely relevant. For example, the learner may not refer to all of the set-up activities when describing vacuum forming or may accurately describe how to drill a hole when the hole would actually be generated during a sand-casting process.

### Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner work. This may mean that learners should be supervised.

Resources: all learners should have access to the same types of resource to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 6: Engineering Materials
- Unit 8: Machining Techniques
- Unit 9: Engineering Design
- Unit 10: Engineering Fitting and Assembly
- Unit 13: Operations and Maintenance of Mechanical Systems and Components.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- working with an industrial partner to develop a range of case studies to aid the delivery and preparation for assessment of the unit. Case studies could provide details about a range of engineering products and learners could explore the selection of specific materials and processes to manufacture the component parts
- units delivered or co-delivered by industry practitioners; this could take the form of master classes or guest lectures, e.g. centres could arrange for practitioners who work in the engineering sector, such as technicians, to demonstrate the disassembly of engineering products that their company produce, and to provide specific information about the materials used in component parts and the processes used to manufacture them.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- identifying and selecting the most appropriate materials and manufacturing processes for engineering products based on factors such as purpose, function, features and scale of production.

### Communication

- understanding the use and importance of written and diagrammatic communication methods in order to convey information clearly.

# Unit 4: Engineering Maintenance

Level: **2**
Unit type: **Pearson Set Assignment**
Guided learning hours: **30**

## Unit in brief

Learners will resource and carry out planned maintenance activities on both mechanical and electrical equipment.

## Unit introduction

When a car breaks down, or will not start, it is often because it has been poorly maintained. Similarly, if machinery breaks down, it is probably down to insufficient maintenance. A lack of maintenance can be dangerous – and it can also be very expensive. It is therefore vitally important that equipment and machinery are repaired, adjusted and maintained in order to ensure that they continue to perform their intended functions. In order to demonstrate maintenance principles, you will learn how to resource and carry out practical maintenance activities on both mechanical and electrical engineering products or systems.

## Assessment

This unit has a Pearson Set Assignment. Learners must complete a Pearson Set Assignment Brief.

## Learning aims

In this unit you will:

**A** Carry out a mechanical maintenance task safely on an engineering product or system

**B** Carry out an electrical maintenance task safely on an engineering product or system.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Carry out a mechanical maintenance task safely on an engineering product or system | **A1** Preparing for a mechanical maintenance activity<br>**A2** Carrying out a mechanical maintenance activity<br>**A3** Closing down the work area | This unit is assessed through a Pearson Set Assignment. |
| **B** Carry out an electrical maintenance task safely on an engineering product or system | **B1** Preparing for an electrical maintenance activity<br>**B2** Carrying out a low voltage electrical maintenance activity<br>**B3** Closing down the work area | |

# Content

## Learning aim A: Carry out a mechanical maintenance task safely on an engineering product or system

### A1 Preparing for a mechanical maintenance activity

General safe working practices whilst preparing for and undertaking a maintenance activity.

- Identification of risks, associated hazards and their control.
- Selecting and wearing appropriate personal protective equipment (PPE).
- Obtaining and understanding technical instructions such as parts lists, assembly drawings, job cards.
- Obtaining suitable tools such as spanners, sockets sets, screwdrivers, wrenches, mallets.
- Obtaining suitable equipment such as buckets, rags/cloths, specialist equipment such as pullers, torque wrenches.
- Obtaining consumable items such as seals, greases, oils, filters, brake pads/brake shoes, locking devices such as locking wire, split/cotter pins, lock nuts.
- Carrying out pre-use checks on tools and equipment to ensure they are safe and in a usable condition.
- Safe isolation of the product or system to prevent inadvertent operation.

### A2 Carrying out a mechanical maintenance activity

- Following correct procedures to carry out a given mechanical maintenance task such as replacement of consumable components, changing the lubricant in a mechanical system, changing vehicle brake pads, changing filter elements.
- Working safely at all times.
- Completing any appropriate maintenance records such as equipment maintenance logbooks, computer-based maintenance records, inspection checklists, oil replenishment records, resetting vehicle onboard maintenance indicators.
- Completing any appropriate post-maintenance checks such as leak checks, functional checks, range and freedom of movement, freedom of rotation, loose item checks.

### A3 Closing down the work area

- Leaving the work area clean, tidy and safe.
- Returning technical instructions and tools and equipment on completion of the task.
- Correct disposal of waste materials.

## Learning aim B: Carry out an electrical maintenance task safely on an engineering product or system

### B1 Preparing for an electrical maintenance activity

General safe working practices whilst preparing for and undertaking a low voltage maintenance activity.

- Identification of risks, associated hazards and their control.
- Selecting and wearing appropriate personal protective equipment (PPE).
- Obtaining and understanding technical instructions such as parts lists, assembly drawings, job cards, wiring diagrams.
- Obtaining suitable tools such as spanners, sockets sets, screwdrivers, wrenches, pilers.
- Obtaining suitable equipment such as rags/cloths, multi-meters, torches/inspection lamps, specialist equipment such as torque wrenches, torque screwdrivers, circlip pliers.
- Obtaining consumable items such as seals, bulbs/filaments, switches, motors, sensors, locking devices such as locking wire, split/cotter pins, lock nuts.
- Carrying out pre-use checks on tools and equipment to ensure they are safe and in a usable condition.
- Safe isolation of the product or system to prevent inadvertent operation such as lock-offs, circuit breakers, safety interlocks.

### B2 Carrying out a low voltage electrical maintenance activity

- Following correct procedures to carry out a given electrical maintenance task such as changing the brushes in a motor, replacement of a burnt-out component, replacement of a faulty switch, replacement of a circuit board within a domestic appliance, replacement of a consumable items.
- Working safely at all times.
- Completing any appropriate maintenance records such as equipment maintenance logbooks, computer-based maintenance records, inspection checklists
- Completing any appropriate post-maintenance checks such as functional checks, built-in-test-equipment (BITE) tests.

### B3 Closing down the work area

- Leaving the work area clean, tidy and safe.
- Returning technical instructions and tools and equipment on completion of the task.
- Correct disposal of waste materials.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Carry out a mechanical maintenance task safely on an engineering product or system** | | **A.D1** Complete a mechanical maintenance task safely, accurately and effectively, showing a high level of skill. |
| **A.P1** Manage a work area safely when carrying out a mechanical maintenance task.<br>**A.P2** Select the tools, equipment, consumable items and technical instructions required to complete a mechanical maintenance task.<br>**A.P3** Complete a mechanical maintenance task safely, filling in the required documentation. | **A.M1** Complete a mechanical maintenance task safely and accurately, showing a good level of skill. | |
| **Learning aim B: Carry out an electrical maintenance task safely on an engineering product or system** | | **B.D2** Complete an electrical maintenance task safely, accurately and effectively, showing a high level of skill. |
| **B.P4** Manage a work area safely when carrying out an electrical maintenance task.<br>**B.P5** Select the tools, equipment, consumable items and technical instructions required to complete an electrical maintenance task.<br>**B.P6** Complete an electrical maintenance task safely, filling in the required documentation. | **B.M2** Complete an electrical maintenance task safely and accurately, showing a good level of skill. | |

## Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners.

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a workshop environment and appropriate engineering products and systems so that mechanical and electrical maintenance activities can be carried out
- relevant manufacturers' service manuals, data sheets, parts lists, diagrams and drawings (technical instructions)
- relevant tools, equipment and consumable items as appropriate to the engineering products and systems being maintained.

### Essential information for assessment decisions

### Learning aim A

**For Distinction standard**, learners will:

- Be safe and methodical at all times when completing a mechanical maintenance task.
- Effectively complete a mechanical maintenance task on an engineering product or system with a high level of skill and showing a capability to adapt their approach to the task as required. For example, they may adapt their approach to overcome any problems that may emerge, such as a bolt shearing during a dismantling process, or to make sensible adjustments to ensure that they are working both effectively and efficiently.
- Accurately complete all the visual and specific checks detailed in the technical instructions and fill in maintenance documentation accurately so that the engineering product or system can be returned to use in a timely fashion.

**For Merit standard**, learners will:

- Be organised and observe safe working practices at all times.
- Select the most appropriate tools, equipment, consumable items and technical instructions required to complete a mechanical maintenance task.
- Complete a mechanical maintenance task on an engineering product or system with a good level of skill and showing confidence in their working. They will complete the task accurately and will check their progress against the technical instructions at appropriate stages, but some of their decisions may result in unnecessary extra activities and may slow their progress at times.
- Complete most visual and any specific checks detailed in the technical instructions and fill in maintenance documentation accurately so that the product or system is ready to return to use.

**For Pass standard**, learners will:

- Demonstrate that they can safely manage a maintenance work area by:
  - selecting and using the correct PPE
  - following required procedures to control any risks
  - leaving it in a clean and tidy condition and by storing tools, equipment and technical instructions in the correct place upon completion of the mechanical maintenance task
  - disposing of waste materials appropriately.

- Select the tools, equipment, consumable items and technical instructions required to complete a mechanical maintenance task. They may not be the most effective or efficient tools and equipment available to them, for example they might choose to use an adjustable spanner instead of a correctly sized open-ended or ring spanner, but they will be suitable.
- Appropriately complete a mechanical maintenance task on an engineering product or system and fill in maintenance documentation.

### Learning aim B

**For Distinction standard**, learners will:

- Be safe and methodical at all times when completing an electrical maintenance task.
- Effectively complete an electrical maintenance task on an engineering product or system with a high level of skill and showing a capability to adapt their approach to the task as required. For example, they may adapt their approach to overcome any problems that may emerge, such as a wire breaking during a dismantling process, or to make sensible adjustments to ensure that they are working both effectively and efficiently.
- Accurately complete all the visual and specific checks detailed in the technical instructions and fill in electrical documentation accurately so that the engineering product or system can be returned to use in a timely fashion.

**For Merit standard**, learners will:

- Be organised and observe safe working practices at all times.
- Select the most appropriate tools, equipment, consumable items and technical instructions required to complete an electrical maintenance task.
- Complete an electrical maintenance task on an engineering product or system with a good level of skill and showing confidence in their working. They will complete the task accurately and will check their progress against the technical instructions at appropriate stages, but some of their decisions may result in unnecessary extra activities and may slow their progress at times.
- Complete most visual and any specific checks detailed in the technical instructions and fill in maintenance documentation accurately so that the product or system is ready to return to use.

**For Pass standard**, learners will:

- Demonstrate that they can safely manage a maintenance work area by:
  - selecting and using the correct PPE
  - following required procedures to control any risks
  - leaving it in a clean and tidy condition and by storing tools, equipment and technical instructions in the correct place upon completion of the electrical maintenance task
  - disposing of waste materials appropriately.
- Select the tools, equipment, consumable items and technical instructions required to complete an electrical maintenance task. They may not be the most effective or efficient tools and equipment available to them, for example they might choose to use a spanner instead of a torque screwdriver to tighten the cable clamp nuts on an electrical distribution block, but they will be suitable.
- Appropriately complete an electrical maintenance task on an engineering product or system and fill in maintenance documentation.

## Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner work. This may mean that learners should be supervised.

Resources: all learners should have access to the same types of resource to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 10: Engineering Fitting and Assembly
- Unit 13: Operations and Maintenance of Mechanical Systems and Components
- Unit 16: Application of Quality Control and Measurement in Engineering
- Unit 22: Electrical and Electronic Circuit Construction and Testing
- Unit 31: Vehicle Maintenance Techniques
- Unit 32: Vehicle Engine Technology.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to work safely in hazardous environments and ensure that they, and others around them, are safe when completing maintenance procedures.

# Unit 5: Mathematics for Engineering Technicians

Level: **2**
Unit type: **Pearson Set Assignment**
Guided learning hours: **30**

## Unit in brief

Learners will consider the mathematical methods that are needed to provide solutions to contextualised engineering problems.

## Unit introduction

Have you ever wondered why engineers use mathematics to solve many of the interesting challenges they encounter on a day-to-day basis? For example, calculating the direct stress in a material, using trigonometry to mark out steel plate before fabricating it, and/or working out the resistance in a circuit. There are many reasons for completing these types of calculation, including to save the engineers time and money, and to ensure that challenges are solved safely and effectively.

This unit is the starting point for you to gain the mathematical skills needed to solve many of the interesting challenges that engineers face on a day-to-day basis. You will start by looking at number work and arithmetical methods before moving on to consider equations and formulae. These are topics that engineers work with all the time – for example Ohm's law ($V = IR$) and Newton's second law of motion ($F = ma$).

You will then investigate how to present and process numerical engineering data relating to quantities that vary in relation to each other. For example, what happens to the current in a circuit if the voltage changes? These problems can often be solved by plotting and interpreting a graph of the variables involved. Another useful technique that you need to know about is mensuration. This process involves working out the areas of regular and compound two-dimensional shapes, and also the volumes of regular and compound three-dimensional objects such as cylinders and spheres. The final part of the unit is an introduction to trigonometry, which allows you to work out the lengths of components and the angles at which they should be set.

## Assessment

This unit has a Pearson Set Assignment. Learners must complete a Pearson Set Assignment Brief.

## Learning aims

In this unit you will:

**A** Examine how arithmetic, algebraic and graphical methods are used to solve engineering problems

**B** Examine how mensuration and trigonometry are used to solve engineering problems.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Examine how arithmetic, algebraic and graphical methods are used to solve engineering problems | **A1** Arithmetic methods<br>**A2** Algebraic methods<br>**A3** Graphical methods | This unit is assessed through a Pearson Set Assignment. |
| **B** Examine how mensuration and trigonometry are used to solve engineering problems | **B1** Areas and volumes of regular and compound shapes and three-dimensional objects<br>**B2** Trigonometry | |

# Content

## Learning aim A: Examine how arithmetic, algebraic and graphical methods are used to solve engineering problems

### A1 Arithmetic methods

Arithmetic methods for solving engineering problems.

- Routine arithmetic methods involve:
  - addition, subtraction, multiplication and division of whole and decimal numbers
  - positive and negative integers
  - circles – radius ($r$), diameter ($2r$), circumference ($\pi d$)
  - arithmetic precedence (BIDMAS rule) – brackets, indices, division, multiplication, addition, subtraction
  - powers of numbers, including squares and cubes
  - square roots of numbers
  - expressing numbers using standard form and engineering notation
  - solving simple engineering formulae by substituting values
  - reasonable answers – approximations
  - rounding – significant figures, decimal places
  - use of symbols $=$, $\neq$, $<$, $>$, $\leq$, $\geq$
- Non-routine arithmetic methods involve the following topics and/or multiple steps to complete the calculation:
  - addition, subtraction, multiplication, division and simplification of fractions
  - cube root of numbers
  - engineering calculations involving ratios
  - calculation and application of percentages.

### A2 Algebraic methods

Algebraic methods for solving engineering equations and evaluating engineering formulae.

- Routine algebraic methods involve:
  - changing the subject of an equation
  - substitution of numerical values into algebraic equations
  - transposing linear equations and engineering formulae
  - solving linear equations for:
    - a single variable
    - systems of linear equations
  - different forms of engineering equations such as
    $x + 3 = 8$, $6m + 11 = 25 - m$, $3x = 7(8 - 2x)$, $2(x+1) = 8$, $\frac{7}{x} = 2$, $\frac{4}{t} = \frac{2}{3}$
  - substituting values into engineering formulae
  - engineering formulae:
    electrical – $V = IR$, $R_T = R_1 + R_2 + R_3 ...$, $P = VI$ or $P = I^2R$, $\tau = RC$, $Q = CV$, $T = 1/f$
    mechanical – $v = u + at$, $s = ½(u + v)t$, $F = ma$, $W = Fs$, $P = Fv$, $PE = mgh$, $\sigma = F/A$.

- Non-routine algebraic methods involve the following topics and/or multiple steps to complete the calculation:
  - engineering formulae:

    electrical – $C = \varepsilon A/d$, ½$QV$ = ½$CV^2$, $V = V_0 \sin 2\pi ft$, $X_c = \frac{1}{2\pi fC}$

    mechanical – $s = ut + ½at^2$, $v^2 = u^2 + 2as$, ½$mv^2 = mgh$
  - chained calculations, such as $(a + b)^n \times (c + d)^{1/n}$, $\frac{(a \times b)}{(c + d + e)^n}$

### A3 Graphical methods

- Routine graphical methods involve:
  - plotting a linear relationship from given data – scale, axis labels, title, line of best fit
  - plotting a linear relationship from given data
  - extracting/interpreting information from straight-line graphs – gradient, intercept and the equation of a straight line
  - identify coordinates in all four quadrants
  - graph interpretation to determine engineering parameters, such as the stiffness of a spring, velocity of a moving body, resistance of an electrical circuit.
- Non-routine graphical methods involve the following topics and/or multiple steps to complete the calculation:
  - plotting a non-linear/curved relationship from given data – such as electrical power ($P = I^2R$).

## Learning aim B: Examine how mensuration and trigonometry are used to solve engineering problems

### B1 Areas and volumes of regular and compound shapes and three-dimensional objects

Measurement of area.

- Routine methods involve:
  - shapes, such as rectangle, triangle, circle
  - compound shapes, such as L-shaped angle, I-sections, T-sections, U-shaped channel, trapezium, circular ring, rectangular plate with through hole(s).
- Non-routine methods involve the following topics and/or multiple steps to make connections between different topics:
  - complex shapes, such as sphere, curved surface area of a cylinder, 3D object.

Measurement of volume.

- Routine methods involve:
  - solid objects, such as rectangular prism, cylinder, cone, sphere, hemisphere.
- Non-routine methods involve the following topics and/or multiple steps to complete the calculation:
  - complex hollow shapes, such as tube, cone, sphere
  - complex compound objects (hollow and solid), such as truncated cone, cylinder with hemispherical ends, cylinder with conical end, circular tube, I-beam, L-shaped bracket, T-section.

### B2 Trigonometry

Trigonometric methods for solving engineering problems.

- Routine trigonometric methods involve:
  - Pythagoras' theorem – side lengths of right-angled triangles
  - relationships – right-angled triangle functions (sine, cosine, tangent)
  - right-angled triangles – side lengths and angles.
- Non-routine trigonometric methods involve the following topics and/or multiple steps to complete the calculation:
  - trigonometric relationship ($\tan\theta = \sin\theta/\cos\theta$)
  - compound shapes – solve unknown dimensions and angles for a combination of rectangles and triangles.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Examine how arithmetic, algebraic and graphical methods are used to solve engineering problems** | | **AB.D1** Solve engineering problems accurately using routine and non-routine methods correctly. |
| **A.P1** Solve engineering problems by applying routine arithmetic methods correctly.<br>**A.P2** Solve engineering problems by applying routine algebraic methods correctly.<br>**A.P3** Solve engineering problems by applying routine graphical methods correctly. | **A.M1** Solve engineering problems accurately using routine methods and apply non-routine methods correctly. | |
| **Learning aim B: Examine how mensuration and trigonometry are used to solve engineering problems** | | |
| **B.P4** Calculate areas by applying routine methods correctly.<br>**B.P5** Calculate volumes by applying routine methods correctly.<br>**B.P6** Solve engineering problems by applying routine trigonometric methods correctly. | **B.M2** Solve engineering problems accurately using routine methods and apply non-routine methods correctly. | |



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## Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners.

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to scientific calculators and mathematical instruments.

### Essential information for assessment decisions

### Learning aims A and B

**For Distinction standard**, learners will:

- Produce evidence that demonstrates that they can consistently apply routine and non-routine arithmetic, algebraic, graphical, mensuration and trigonometric methods correctly to find accurate solutions to engineering problems.
- Show clear and logical steps when producing solutions to problems that may include minimal errors such as those associated with transposition or rounding.
- Provide answers to an appropriate degree of precision and accuracy that will be presented in an appropriate form.

**For Merit standard**, learners will:

- Produce evidence that demonstrates that they can consistently apply routine arithmetic, algebraic, graphical, mensuration and trigonometric methods correctly to find accurate solutions to engineering problems.
- Produce evidence that demonstrates that they can apply non-routine arithmetic, algebraic, graphical, mensuration and trigonometric methods correctly to find solutions to engineering problems. However, the final answer may be incorrect, if, for example, an incorrect value has been substituted into an equation.
- Show clear and logical steps when producing solutions that use routine methods. However, with non-routine methods, there may be some arithmetic errors, but these are likely to be carried through into subsequent working using a suitable method.
- Provide answers to an appropriate degree of precision although they may not always be presented in an appropriate form.

**For Pass standard**, learners will:

- Produce evidence that demonstrates that they can apply routine arithmetic, algebraic, graphical, mensuration and trigonometric methods correctly to find plausible solutions to engineering problems.
- Show mostly suitable steps when producing solutions that use routine methods. However, some more obvious errors, such as substituting incorrect values into the correct equation, may be carried through into subsequent working.
- Provide answers that show some accuracy but are likely not to be presented in an appropriate form; for example not provided to two decimal places (DP).

## Assessment controls

Time: this assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.

Supervision: you should be confident of the authenticity of learner work. This may mean that learners should be supervised.

Resources: all learners should have access to the same types of resource to complete the assignment.

Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 8: Machining Techniques
- Unit 10: Engineering Fitting and Assembly
- Unit 19: Data Capture and Interpretation
- Unit 22: Electrical and Electronic Circuit Construction and Testing.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- technical workshops involving experts from local organisations that apply relevant mathematical techniques to solve engineering problems
- contribution of ideas to unit assignment/project materials from professionals.

# Unit 6: Engineering Materials

Level: **2**
Unit type: **Internal**
Guided learning hours: **30**

## Unit in brief

Learners will test and investigate engineering materials, their properties and the heat treatments and forms of supply used, as well as the sustainable use of the materials as a resource.

## Unit introduction

Have you ever wondered how large commercial aircraft take off and fly thousands of passengers and their luggage to destinations around the world? One of the answers lies in the ability of skilled engineers to successfully identify and use a range of materials that combine a number of factors, such as strength to weight ratio, cost and availability. It is also essential for engineers to select the correct material if a smaller product or a replaced component is to be fit for its intended purpose.

This unit will develop your knowledge of a range of engineering materials as well as their properties and suitability for engineering applications. You'll also carry out testing activities and will investigate heat treatment processes and their effect on engineering materials.

Importantly, this unit will introduce you to the sustainability issues that surround the use of a range of engineering materials and you will come to understand how this is a major consideration when developing products for the present day and in the future. This includes decisions around forms of supply.

## Learning aims

In this unit you will:

**A** Investigate properties, heat treatment and testing of engineering materials

**B** Investigate the selection and sustainable use of engineering materials and forms of supply

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate properties, heat treatment and testing of engineering materials | **A1** Types of engineering material<br>**A2** Applications of engineering materials<br>**A3** Properties of engineering materials<br>**A4** Heat treatments<br>**A5** Tests on engineering materials | A portfolio of evidence from conducting practical mechanical testing of engineering materials. Learners will provide annotated photographs of the testing processes as well as a report detailing the results obtained and how these can be used to support material choices for engineering applications. Learner practical work will be supported by assessor observation records. |
| **B** Investigate the selection and sustainable use of engineering materials and forms of supply | **B1** Selection for engineering activities and products<br>**B2** Sustainable use of materials<br>**B3** Forms of supply | A report detailing material supply forms their sustainable use within given engineering situations. |

## Content

### Learning aim A: Investigate properties, heat treatment and testing of engineering materials

#### A1 Types of engineering material

- Ferrous metals, including low and medium carbon steels, high carbon steels, stainless steel and cast iron.
- Non-ferrous metals, including aluminium, copper, zinc, brass, lead, titanium, tungsten carbide, superalloys (nickel-based and cobalt-based) and ceramics (boron carbide and cubic boron nitride).
- Composite materials, including plywood, glass reinforced plastic (GRP), medium density fibreboard (MDF) carbon fibre and aramid fibre.
- Thermoplastic polymer materials, including acrylic, polyvinyl chloride (PVC), polythene (PET), polystyrene, nylon and polycarbonate.
- Thermosetting polymer materials, including formica, melamine, epoxy resin and polyester resin.
- Smart materials, including shape memory alloys (SMAs), shape memory polymers, electrochromic, piezoelectric, quantum tunnelling composite (QTC).

#### A2 Applications of engineering materials

Typical example applications of engineering materials taken from the following sectors.

- Aerospace including engines, wings, rotor blades, landing gear.
- Automotive including engines, body panels, wheels, exhaust systems, braking systems, bumpers.
- Communications including satellite dishes, smartphones, wireless routers, transmission masts.
- Electrical/electronic including white goods, televisions, games consoles, laptop computers.
- Mechanical including bicycles, wheelbarrows, mechanic's vices, fixtures and fittings.

#### A3 Properties of engineering materials

- Mechanical, including density, tensile strength, shear strength, compressive strength, hardness, stiffness, toughness/brittleness, malleability/ductility, elasticity and plasticity, wear resistance.
- Electromagnetic, including electrical conductivity, electrical resistance, paramagnetism/diamagnetism/ferromagnetism.
- Chemical, including resistance to corrosion and environmental degradation, reactivity.
- Thermal, including melting point, thermal conductivity, thermal expansion.

#### A4 Heat treatments

Processes that rely on heating to a certain temperature, time at that temperature and speed of cooling for ferrous materials, including:

- Annealing.
- Normalising.
- Hardening.
- Tempering.
- Case hardening.

### A5 Tests on engineering materials

Mechanical tests, including:

- Tensile/ductility test (loading a suspended wire specimen and recording the breaking load and amount of permanent extension).
- Shear strength test (using bench shears or tin snips).
- Hardness test (centre punch, file or saw used to assess surface hardness or a test in which a hardened steel ball bearing is dropped from a given height and its rebound measured to assess surface hardness).
- Impact test (striking a specimen held in a vice with a hammer and noting its effect).
- Bending stiffness test (clamping one end of a specimen horizontally, loading the free end and measuring the deflection).

## Learning aim B: Investigate the selection and sustainable use of engineering materials and forms of supply

### B1 Selection for engineering activities and products

- Selection through activity, e.g. design, construction, manufacture, operations, or maintenance.
- Selection through use in a product, e.g. an engineered product consisting of multiple production methods and forms of supply, such as a bicycle or office chair.

### B2 Sustainable use of materials

- Raw material extraction and processing.
- Less volatile organic compounds.
- Reducing material use.
- Reusing materials and products where applicable.
- Recycling materials or using recycled materials.
- Waste management.

### B3 Forms of supply

- Metal forms, including bar stock, sheet materials, pipe/tube, wire, plate, rolled steel sections, pressings, castings, ingots, forgings, extrusions.
- Polymer/composite forms, including sheet, pipe/tube, mouldings, powders, granules, resins, film.
- Size, including diameters, thickness and gauge.
- Surface finish, including bright drawn, cold drawn, plated, painted and plastic coated.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate properties, heat treatment and testing of engineering materials** | | **A.D1** Evaluate the choice of materials for two engineering applications by interpreting the results of tests carried out and considering material properties and the impact of the heat treatment process used. |
| **A.P1** Describe the properties of engineering materials.<br>**A.P2** Describe the effects of a heat treatment process on an engineering material.<br>**A.P3** Carry out tests safely on engineering materials. | **A.M1** Explain why the materials were chosen for two engineering applications by using the results of tests carried out and considering material properties and the benefits of the heat treatment process used. | |
| **Learning aim B: Investigate the selection and sustainable use of engineering materials and forms of supply** | | **B.D2** Evaluate the sustainable use of materials for an engineering activity and for an engineering product, including why the forms of supply were suitable. |
| **B.P4** Describe the sustainable use of engineering materials.<br>**B.P5** Describe forms of supply for engineering materials. | **B.M2** Explain the sustainable use of materials for an engineering activity and for an engineering product, including why the forms of supply were selected. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.D1)

Learning aim: B (B.P4, B.P5, B.M2, B.D2)

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## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a variety of finished engineering components and products that illustrate the application of particular materials
- a range of engineering materials, including heat treated materials, in their different forms of supply
- standard workshop tools and equipment used for carrying out mechanical testing.

### Essential information for assessment decisions

Note that the ‘engineering materials’ used in the assignment brief for Unit 6 Learning aim A must be different to those given in the Unit 3 Pearson Set Assignments (PSAs). This means that the assignment brief for Unit 6 will need to be checked against the relevant PSAs each year and possibly updated, as a result, to ensure the ‘engineering materials’ being assessed each year are different.

The assessment activity for Learning aim A must:

- Focus on one engineering application that uses a heat-treated ferrous metal and another engineering application that uses a different type of material (such as non-ferrous metal, composite or polymer) – for example, an annealed medium carbon steel catch plate and a nylon washer.
- Allow learners to carry out at least two simple mechanical tests, one on each of the materials chosen – the tests can be carried out on the materials in their simplest form, for example as a flat sheet or strip.

### Learning aim A

**For Distinction standard**, learners will:

- Consider two different engineering applications and for each application learners will provide an evaluation of at least two different materials that could be used to meet the requirements of the application. As part of the evaluation, learners must consider the results of the mechanical tests carried out and the impact of any heat treatment processes.

**For Merit standard**, learners will:

- Use the results obtained from conducting mechanical tests on a range of engineering materials and explain why materials were chosen for two engineering applications whilst considering the properties of the materials and the benefits of a heat treatment process. For example, learners could explain that carbon fibre is used for manufacturing aircraft panels as it is light weight, whilst also having high stiffness and high tensile and compressive strength. They could also explain the effect that case hardening has on the properties of a ferrous metal thus making it suitable for use in engine camshafts where the bearing surfaces are hardened to resist wear, whilst leaving the bulk of the material in its original tough state.

**For Pass standard**, learners will:

- Choose at least two different types of engineering material and describe the properties of each. For example, learners may choose one ferrous metal and one polymer.
- Safely carry out at least two simple mechanical tests and record the results in a suitable format.
- Research and fully describe the effects that a heat treatment process has on a given engineering material. For example, learners could describe the effects that annealing has on the properties of a given ferrous material.

### Learning aim B

The assessment activity for Learning aim B must:

- Include details of the engineering materials used for an engineering activity and for an engineering product, for example a maintenance activity on a car engine and a bicycle – the chosen activity and product must both include the use of several engineering materials and forms of supply.

**For Distinction standard**, learners will:

- Evaluate the engineering activity and engineering product to understand the materials and supply methods used. Learners must identify alternate forms of supply for each material and use this information to select the forms of supply you would choose in the given situation ensuring that any change in supply form improves sustainability.

**For Merit standard**, learners will:

- Explain the materials used in a given engineering activity and for a given engineering product. As part of the explanation, learners must cover the form that the materials are supplied in and why they are supplied in this manner for the given engineering activity and engineering product. Learners must also explain the sustainability of the materials identified. For example, for press forming of car body panels, steel would be supplied in sheet form on a roll so the manufacturer can cut it to the required stock size of the blank before loading it into the press. They will also explain that the waste material is collected and recycled.

**For Pass standard**, learners will:

- Describe how the use of engineering materials is sustainable. For example, they will describe how steel forms such as sheet and bar stock are manufactured using a mixture of new raw materials and recycled steel products thus reducing the need to extract and process raw materials. Learners must cover all engineering material types detailed in the unit content.
- Describe the current forms of supply of engineering materials, covering the material, size, shape, finish and any codes or symbols used for identification purposes. Learner must cover all engineering material types detailed in the unit content.



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## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 8: Machining Techniques
- Unit 10: Engineering Fitting and Assembly.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate engineering materials for a range of engineering applications.

### Managing information

- Collecting information through research or testing, recording findings in a structured way and interpreting data.

### Self-management and development

- Development of practical skills when handling testing equipment.
- Develop of research skills to support decision making.

# Unit 7: Engineering Drawing

Level: **2**

Unit type: **Internal**

Guided learning hours: **60**

## Unit in brief

Learners will use sketching techniques and two-dimensional (2D) and three-dimensional (3D) Computer-aided Design (CAD) commands to generate drawings and models that communicate engineering information.

## Unit introduction

Did you know that technical sketching and Computer-aided Design (CAD) drawings and models are used by engineers all over the world to communicate technical information?

In this unit, you will learn the skills and techniques that you need to generate sketches of shapes, engineering tools and components and how to develop them into 2D drawings and 3D models using CAD systems.

This unit will help you to understand and use the most appropriate methods to communicate engineering information through the use of technical sketching techniques.

You will also learn how to generate 2D engineering drawings and electronic circuit diagrams using CAD commands, as well as how to produce 3D engineering models using a CAD system.

Importantly, this unit will make you aware of how important it is that you generate sketches and drawings to a recognisable standard that can be easily understood by other engineers so there is no chance of misinterpretation.

## Learning aims

In this unit you will:

**A** Use technical sketching to draw engineering tools or components

**B** Use a Computer-aided Design (CAD) system to produce 2D engineering drawings

**C** Use a Computer-aided Design (CAD) system to produce 3D engineering models.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Use technical sketching to draw engineering tools or components | **A1** Technical sketching techniques<br>**A2** Shapes, engineering tools and components | A portfolio containing a range of evidence of engineering sketches, annotated photographs, and observation statements. |
| **B** Use a Computer-aided Design (CAD) system to produce 2D engineering drawings | **B1** Commands to produce a 2D engineering drawing<br>**B2** Commands to produce an electronic circuit diagram | Use of a CAD system to produce and output a portfolio of 2D CAD engineering drawings and circuit diagrams. |
| **C** Use a Computer-aided Design (CAD) system to produce 3D engineering models | **C1** Commands to produce a 3D engineering model | Use of a 3D CAD system to produce and output a portfolio of 3D CAD engineering drawings and models. |

# Content

## Learning aim A: Use technical sketching to draw engineering tools or components

### A1 Technical sketching techniques

Equipment and techniques for developing sketches:

- equipment, such as paper (plain, squared, isometric), pencil, eraser
- techniques, including oblique (cavalier and cabinet), isometric and orthographic projections (single and linked views, first and third angle)
- sketching in proportion and dimensioning (overall sizes, details).

### A2 Shapes, engineering tools and components

Creation of shapes, engineering tools and components:

- solids, including cube, rectangular block, sphere
- hollow objects, including circular tube, square tube
- standard components, such as nuts, bolts, screws, shafts, gears, housings
- engineering tools, such as bicycle spanner, drill gauge, support bracket, pulleys
- engineering components, such as brackets, vee block, clamps.

## Learning aim B: Use a Computer-aided Design (CAD) system to produce 2D engineering drawings

### B1 Commands to produce a 2D engineering drawing

CAD commands to output 2D orthographic projection drawings to a recognisable international standard:

- for set-up, including paper size, snap, grid, units, type of line
- for drawing lines, circles, text, polygons, rectangles, arcs
- for manipulation, including move, copy, fillet, mirror, trim, rotate, chamfer, zoom, pan
- for annotation, text and dimensioning
- for editing, including erase, undo, redo
- for features, including hatching
- for outputting to print or plot
- for saving to a file format, folder/directory
- for a drawing template, including border, title block, projection, scale, drawing number, title of drawing, material, names of drawing creator and who checks/authorises the drawing.

### B2 Commands to produce an electronic circuit diagram

CAD commands to output an electronic circuit diagram to a recognisable international standard:

- for set-up, including paper size, snap, grid, units, type of line
- for drawing circuit components and connections
- for outputting to print or plot
- for insertion of standard symbols
- for saving to a file format, folder/directory

- for annotation of component name or description
- for manipulation, including copy/duplicate, move, rotate/revolve, erase, stretch, trim, scale, zoom-in, zoom-out
- for features, including circle, text, hatch.

## Learning aim C: Use a Computer-aided Design (CAD) system to produce 3D engineering models

### C1 Commands to produce a 3D engineering model

CAD commands to output 3D engineering models:

- for configuration, including origin, units, snap, grid, planes (XY, XZ and YZ)
- for the use of layers, coordinate system, file types and file systems
- for 2D sketches, including basic shape, dimensions, modifications
- for 3D features, such as threads, male and female holes – plain, drilled, threads, countersunk, fillet, chamfer
- for conversion of a 2D sketch to a 3D model, including rotate about an axis, revolve, extrude
- for display, including pan, zoom
- for editing, including erase, extend, trim, rotate
- for outputting to print or plot.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Use technical sketching to draw engineering tools or components</td><td rowspan="2">A.D1 Refine correctly proportioned and accurate orthographic and isometric or oblique projection sketches of an engineering tool or component.</td></tr>
<tr><td>A.P1 Create a recognisable orthographic projection sketch of an engineering tool or component.<br>A.P2 Create a recognisable isometric or oblique projection sketch of an engineering tool or component.</td><td>A.M1 Produce mainly accurate orthographic and isometric or oblique projection sketches of an engineering tool or component.</td></tr>
<tr><td colspan="2">Learning aim B: Use a Computer-aided Design (CAD) system to produce 2D engineering drawings</td><td rowspan="4">BC.D2 Refine, using 2D and 3D CAD commands, an accurate orthographic projection drawing of an engineering tool or component, a 3D model of the engineering tool or component and a diagram of an electronic circuit.</td></tr>
<tr><td>B.P3 Create, using 2D CAD commands, a recognisable orthographic projection drawing of an engineering tool or component.<br>B.P4 Create, using CAD commands, a recognisable diagram of an electronic circuit.</td><td>B.M2 Produce, using 2D CAD commands, a mainly accurate orthographic projection drawing of an engineering tool or component and diagram of an electronic circuit.</td></tr>
<tr><td colspan="2">Learning aim C: Use a Computer-aided Design (CAD) system to produce 3D engineering models</td></tr>
<tr><td>C.P5 Create, using 3D CAD commands, a recognisable 3D model of an engineering tool or component.</td><td>C.M3 Produce, using 3D CAD commands, a mainly accurate 3D model of an engineering tool or component.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aims: B and C (B.P3, B.P4, C.P5, B.M2, C.M3, BC.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- technical sketching equipment, including isometric and oblique paper
- a CAD facility, including computers loaded with appropriate 2D and 3D CAD software. In addition, access to a printer/plotter to produce hard copies would assist for assessment
- examples of physical shapes, engineering tools, components and electronic circuits that learners can use to generate the necessary sketches, drawings and models.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Show consistently proportioned sketches for every tool or component produced. Typical examples are toolmakers clamps, pulleys, cast housings.
- Create tools and components using the correct techniques, both in orthographic and isometric or oblique form with all the views orientated correctly.
- Create a drawing template so that a portfolio of drawings can be developed.
- Include evidence to linked orthogonal drawings in first or third angle with all views correctly aligned and appropriate dimensions included. The isometric or oblique views will most likely be on unlined paper and created at the correct angles. Overall, the drawings will show some adherence to international standards and be clear for a third party to understand.

**For Merit standard**, learners will:

- Show proportioned sketches for every tool or component produced. Typical examples are vee blocks, square tubes, and drill gauges. The tools and components should be created both in orthographic and isometric or oblique form with most of the views orientated correctly.
- Create a drawing template used so that a portfolio of drawings can be developed.
- Include evidence to linked single orthogonal sketches in first or third angle with some views included and partially aligned, and some appropriate dimensions included, inappropriately positioned, or inconsistently applied. The isometric or oblique views will most likely be on lined paper and created at suitable angles. Overall, the sketches will show some adherence to international standards that generally meets its purpose.

**For Pass standard**, learners will:

- Show sketches for every tool or component produced. Typical examples are bicycle spanners, shafts, ball bearings, circular tubes, and plate gauges. The tools and components should be created both in orthographic and isometric or oblique form with some of the views orientated correctly.
- Create a basic drawing frame so that a portfolio of drawings can be developed.
- Include evidence to linked orthogonal sketches in probably a mix of first or third angle with a limited number of views included and possibly not aligned, and some dimensions included, incorrectly positioned, or inconsistently applied. The isometric or oblique views will most likely be on lined paper and created with little awareness of the suitable angles. Overall, the sketches will show limited adherence to international standards that partially meets its purpose.

### Learning aims B and C

**For Distinction standard**, learners will:

- Show consistently proportioned 2D drawings and 3D models of every tool or component produced. Typical examples are toolmakers clamps, pulleys, cast housings, resistor series and parallel circuits, capacitor series and parallel circuits. (Please note a different tool or component needs to be chosen from the item selected for the Pass and Merit grades.)
- Show the tools and components, created using the correct drawing and modification commands using a range of screen dumps, both in orthographic form and as 3D model.
- Show in orthographic form the views orientated correctly and dimensioning placed and oriented correctly. The orthographic drawing needs to be created using 2D commands, not extracted from the 3D model.
- Show the circuit diagram with horizontal and vertical lines, with correctly connected and correctly labelled components.
- Create and use a drawing template so that a portfolio of drawings can be developed.
- Output the 2D and 3D models to a printer or plotter. Produce a range of drawings, including orthogonal drawings and a 3D shaded/solid model. Overall, the drawings will show some adherence to international standards and be clear for a third party to understand.

**For Merit standard**, learners will:

- Show dimensioned 2D and 3D drawings and a circuit diagram for every circuit, tool or component produced. Typical examples are vee blocks, square tubes and drill gauges, resistor series and parallel circuits, capacitor series and parallel circuits.
- Create circuit diagrams, engineering tools and components using the drawing and modification commands. In orthographic form all the views need to be orientated well and a minimum of six dimensions suitably applied.
- Create orthographic drawing 2D commands, not extracted from the 3D model. Learners will show the circuit diagram with mainly horizontal and vertical lines, with connected and labelled components.

- Create 3D models from commands such as extrude and rotate to create solid models. Learners need to consider the complexity of the engineering tool or component prior to starting the 2D exercise, to ensure they can complete the 3D model of the engineering tool or component.
- Create a drawing template so that a portfolio of drawings can be developed. The 2D and 3D drawings and circuit diagrams will be output to a printer or plotter creating a portfolio of drawings, including orthogonal drawings and a circuit diagram. Overall, the drawings will show some adherence to international standards and be clear for a third party to understand.

**For Pass standard**, learners will:

- Show 2D and 3D drawings and a circuit diagram for every circuit, tool or component produced. Typical examples are bicycle spanners, shafts and plate gauges, resistor series and parallel circuits, capacitor series and parallel circuits.
- Create circuit diagrams, tools and components using the drawing and modification commands. In orthographic form all the views need to be reasonably orientated. The orthographic drawing needs to be created using 2D commands, not extracted from the 3D model.
- Show the circuit diagram with connected and possibly some labelled components.
- Create 3D models from commands such as extrude and rotate to create solid models of three different solids, such as a rectangular plate, sphere and a hollow tube.
- Probably create a drawing template so that a portfolio of drawings can be developed.
- Output the 2D drawings and circuit diagrams to a printer or plotter creating a portfolio of drawings, including orthogonal drawings and a circuit diagram. Overall, the drawings will show limited adherence to international standards and that partially meets its purpose.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 2: Engineering Thinking Skills to Create Solutions
- Unit 9: Engineering Design
- Unit 15: Engineering Marking Out
- Unit 17: 3D Printing.

# Unit 8: Machining Techniques

Level: **2**

Unit type: **Internal**

Guided learning hours: **60**

## Unit in brief

Learners will set up machine tools safely and use drilling, turning or milling techniques to produce workpieces that they also quality check.

## Unit introduction

Did you know that you can use drills and lathes or milling machines in different ways when you are machining engineered products? The machines that you will use as part of this unit are some of the most important pieces of engineering equipment. Most Computer Numerically Controlled (CNC) machine tools have been developed from conventional bench or press drills, lathes and milling machines.

This unit will help you to understand the engineering processes that are used to generate and form the shapes and features of workpieces through machining techniques.

You will learn how to select and use a range of tools and work-holding devices so that you can carry out a variety of machining processes. You will also select and use machining techniques that involve shaping or forming with a loss of volume.

You will learn how to set up the machines before you use them and how to monitor the machines while you are using them. You will also learn how to check the items you produce for compliance and accuracy.

Health and safety is vital. Therefore, you will also learn how to set up and operate the machinery safely.

## Learning aims

In this unit you will:

**A** Select tools and work-holding devices for drilling and for turning or milling processes

**B** Safely make workpieces using drilling and turning or milling techniques

**C** Use quality control techniques to check for compliance and accuracy.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Select tools and work-holding devices for drilling and for turning or milling processes | **A1** Tools<br>**A2** Work-holding devices | A report with annotated images/diagrams/photographs detailing the selection of tools and work-holding devices for two workpieces. |
| **B** Safely make workpieces using drilling and turning or milling techniques | **B1** Features of the workpiece<br>**B2** Machining parameters<br>**B3** Working safely | A practical activity involving the safe setting up, machining and quality checking of two workpieces made using drilling and turning or milling techniques.<br>The assessment evidence will include the finished workpieces and a logbook with set-up planning notes, annotated photographs and/or videos with learner narration, quality control records and learner observation records/ witness statements. |
| **C** Use quality control techniques to check for compliance and accuracy | **C1** Checks for compliance and accuracy | |

# Content

## Learning aim A: Select tools and work-holding devices for drilling and for turning or milling processes

### A1 Tools

Tools for specific drilling and turning or milling processes:

- for drilling, e.g. centre drill, drill bit, flat-bottomed drill, counterboring tool, countersinking tool, reamer, tap
- for turning, e.g. turning tools, facing tools, form tools, parting off tools, single point threading, boring bar, recessing tool, centre drill, twist drill, reamer, tap, die, knurling tool
- for milling, e.g. face mills, end mills, slot drills, slotting cutters, slitting saws, profile cutters, twist drills, reamer, boring tools
- tooling materials – steel and other materials, e.g. high-speed steel, cobalt steel, tungsten carbide, diamond.

### A2 Work-holding devices

Work-holding devices for drilling and for turning or milling processes:

- for drilling, e.g. machine vice, clamping direct to machine table, angle plate, vee block and clamps
- for turning, e.g. three jaw chuck with hard jaws, four jaw chuck with hard jaws, centres (live or dead), faceplate, fixed steady or travelling steady
- for milling, e.g. machine vice, clamping direct to machine table, angle plate, vee block and clamps, indexing head/device, rotary table.

## Learning aim B: Safely make workpieces using drilling and turning or milling techniques

### B1 Features of the workpiece

Use of drilling and turning or milling techniques for producing features in a workpiece:

- for drilling – simple features, e.g. through holes, blind holes; more complex features, e.g. flat-bottomed holes, counterbored holes, countersinking, reaming, tapping
- for turning – simple features, e.g. flat faces, parallel diameters; more complex features, e.g. stepped diameters, tapered diameters, drilled holes, bored holes, reamed holes, profile forms, internal threads, external threads, parting off, chamfers, knurls, grooves, undercuts
- for milling – simple features, e.g. flat faces, square faces; more complex features, e.g. parallel faces, angular faces, steps/shoulders, open-ended slots, enclosed slots, recesses, tee slots, drilled holes, bored holes, profile forms, serrations, indexed or rotated forms.

### B2 Machining parameters

Parameters for drilling and turning or milling techniques:

- for drilling – positional, e.g. position of workpiece, position of tool in relationship to workpiece; dynamic, e.g. tooling revolutions per minute (speed), linear feed rate (feed), swarf clearance

- for turning – positional, e.g. position of workpiece, position of tools in relationship to workpiece; dynamic, e.g. workpiece revolutions per minute (speed), linear feed rate (feed), depth of cut for roughing and finishing, swarf clearance
- for milling – positional, e.g. position of workpiece, position of tools in relationship to workpiece; dynamic, e.g. milling cutter revs per minute (speed), linear/table feed rate (feed), depth of cut for roughing and finishing, swarf clearance.

### B3 Working safely

General safe working practices while setting up and using drilling and turning or milling techniques:

- alertness to moving parts
- wearing appropriate personal protective equipment (PPE)
- ensuring machine guards are in place
- use of emergency stop
- machine isolation
- keeping a clean and tidy work area
- removing burrs or sharp edges
- identification of risks, associated hazards and their control.

Specific safe working practices while setting up and using drilling and turning or milling techniques:

- for drilling – handling drilling tools, tool breakage procedure, swarf handling and disposal, cutting fluids
- for turning – handling turning tools, tool breakage procedure, swarf handling and disposal, backlash in machine slides, cutting fluids
- for milling – handling milling tools, tool breakage procedure, swarf handling and disposal, backlash in machine slides, cutting fluids.

## Learning aim C: Use quality control techniques to check for compliance and accuracy

### C1 Checks for compliance and accuracy

Checks for compliance and accuracy relevant to the workpiece and drilling and turning or milling techniques:

- for drilling – visual checks, e.g. workpiece to be free from false tool cuts, burrs and sharp edges removed; specific checks, e.g. dimensional tolerance equivalent to BS EN 22768-1 or BS 4500, surface texture 1.6μm (63 μin), reamed holes within H8, screw threads BS medium fit
- for turning – visual checks, e.g. workpiece to be free from false tool cuts, burrs and sharp edges removed; specific checks, e.g. dimensional tolerance equivalent to BS EN 22768-1 or BS 4500, surface finish 1.6μm (63 μin), reamed or bored holes within H8, screw threads BS medium fit, angles within +/- 1.0 degree
- for milling – visual checks, e.g. workpiece to be free from false tool cuts, burrs and sharp edges removed; specific checks, e.g. dimensional tolerance equivalent to BS EN 22768-1 or BS 4500, surface finish 1.6μm (63 μin), flatness and squareness within 0.125mm per 25mm, angles within +/- 1.0 degree.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Select tools and work-holding devices for drilling and for turning or milling processes</td><td rowspan="2">A.D1 Justify the selection of the most appropriate tools and work-holding devices for safe and accurate drilling and turning or milling processes.</td></tr>
<tr><td>A.P1 Select tools for safe drilling and turning or milling processes.<br>A.P2 Select work-holding devices for safe drilling and turning or milling processes.<br>A.P3 Describe the functions of tools and work-holding devices used for drilling and turning or milling processes.</td><td>A.M1 Explain the selection of tools and work-holding devices for safe and accurate drilling and turning or milling processes.</td></tr>
<tr><td colspan="2">Learning aim B: Safely make workpieces using drilling and turning or milling techniques</td><td rowspan="4">BC.D2 Set, monitor and adjust positional and dynamic parameters effectively when safely using drilling and turning or milling techniques to produce compliant and accurate workpieces with simple and complex features, showing a high level of adaptability and skill.</td></tr>
<tr><td>B.P4 Set positional parameters before machining and set and monitor dynamic parameters during machining when using drilling and turning or milling techniques.<br>B.P5 Produce workpieces with simple and complex features when using drilling and turning or milling techniques, showing some skill.<br>B.P6 Demonstrate conformance with safe working practices when setting up and using drilling and turning or milling techniques.</td><td>B.M2 Set, monitor and adjust positional and dynamic parameters when safely using drilling and turning or milling techniques to produce workpieces with simple and complex features, showing a good level of skill.</td></tr>
<tr><td colspan="2">Learning aim C: Use quality control techniques to check for compliance and accuracy</td></tr>
<tr><td>C.P7 Carry out quality control checks for compliance and accuracy during and after the production of the machined workpieces.</td><td>C.M3 Carry out visual and specific quality control checks to establish compliance and accuracy during and after the production of the machined workpieces.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.D1)

Learning aims: B and C (B.P4, B.P5, B.P6, C.P7, B.M2, C.M3, BC.D2)

For learning aims A, B and C, learners need to provide assessment evidence related to turning or milling as well as drilling machining techniques. It is not necessary or appropriate for learners to cover all three machining techniques for assessment.



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## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- pedestal drills/pillar drills/drill presses and centre lathes or vertical milling machines as required by the learning aims and the *Content* section
- auxiliary equipment, including appropriate tools and work-holding devices as required by the learning aims and the *Content* section
- a range of inspection/measuring equipment suitable for determining the compliance and accuracy of the workpieces to be machined
- a range of engineering drawings for workpieces that include simple and complex features (as defined by the *Content* section) and specific quality requirements that are generated using drilling and turning or milling techniques.

### Essential information for assessment decisions

The two workpieces for the assessment activities between them must include:

- numerous quality requirements, including for surface finishes and dimensional tolerances
- at least one simple and two complex drilling features, as defined in the *Content* section
- at least two simple and two complex turning features, as defined in the *Content* section, or
- at least two simple and two complex milling features, as defined in the *Content* section.

### Learning aim A

**For Distinction standard**, learners will:

- Select the most appropriate tools and work-holding devices for the safe and accurate drilling and turning or milling of the two workpieces to be produced for Learning aims B and C.
- Provide a written justification of why they have chosen the tools and work-holding devices to be used to produce the two workpieces for Learning aims B and C. The justification will provide precise and correct reasons why the chosen tools and work-holding devices are the most appropriate by referring to the features of both of the workpieces to be produced and potential alternative tools and work-holding devices, and will give reasons why they were considered less suitable than the tooling and work-holding devices chosen.

**For Merit standard**, learners will:

- Select suitable tools and work-holding devices for the safe and accurate drilling and turning or milling of the two workpieces to be produced for Learning aims B and C.
- Provide an explanation of why they have chosen the tools and work-holding devices to be used to produce the two workpieces for Learning aims B and C. The explanation will provide accurate reasons why the tools and work-holding devices have been chosen by referring to the features of both of the workpieces to be produced.

**For Pass standard**, learners will:

- Select tools and work-holding devices for the safe drilling and turning or milling of the two workpieces to be produced for Learning aims B and C. They may not be the most effective or efficient tools and work-holding devices available to them, for example they might choose to use a drill bit and flat bottomed drill instead of a counterboring tool to produce a counterbored hole and they might choose to use a 4-jaw chuck instead of a self-centring 3-jaw chuck for holding a round bar.
- Provide a written description of the function of the tools and work-holding devices they have chosen to produce the two workpieces for Learning aims B and C. The descriptions will be specific to drilling and turning or milling processes and will be mostly accurate, for example when referring to a face mill they will cover how it can cut flat faces but may not mention that it must always move in a horizontal direction at a given depth when cutting.

## Learning aims B and C

**For Distinction standard**, learners will:

- Set, monitor and adjust positional and dynamic parameters effectively and in a systematic way when using drilling and turning or milling techniques, showing adaptability and a clear understanding of their importance by modifying them based on, for example, machine feedback, the type of swarf generated, the surface finish being achieved and tool condition, to ensure that both workpieces are compliant and accurate when complete.
- Set up and carry out drilling and turning or milling machining processes with a high level of skill. They will show the capability to manipulate drilling and turning or milling tools, equipment and work-holding devices to machine two compliant and accurate workpieces in an efficient manner.
- Carry out all relevant and necessary quality checks in an accurate manner both during and after the production of the machined workpieces. They will generate detailed and correct quality records to show that they carried out all relevant and necessary quality checks and that they adapted their approach based on the information provided to ensure the compliance and accuracy of both workpieces.
- Demonstrate compliance with safe working practices throughout all of the machining activities.

**For Merit standard**, learners will:

- Set, monitor and adjust positional and dynamic parameters when using drilling and turning or milling techniques to attain the necessary levels of compliance and accuracy, for example by reducing the depth of cut after roughing in order to carry out finishing cuts that will achieve an improved surface finish. There may be some instances where parameters are not effectively set, monitored and adjusted, leading to minor quality issues, such as an unimportant, shallow false cut that can be machined out.
- Set up and carry out drilling and turning or milling machining processes with a good level of skill. They will show the capability to manipulate drilling and turning or milling tools, equipment and work-holding devices to machine two workpieces in an appropriate manner, although some of their choices may slow their progress, for example they may use unnecessary stops and/or sub-optimal dynamic parameter settings.

- Carry out visual and specific quality checks in an accurate manner both during and after the production of the machined workpieces. They will generate suitable quality records to evidence the visual and specific quality checks carried out. They may not always carry out the quality checks at appropriate times during production of the workpieces, leading to minor quality issues such as a burr on a feature.
- Demonstrate compliance with safe working practices throughout all of the machining activities.

**For Pass standard**, learners will:

- Set positional parameters before machining and set and monitor dynamic parameters during machining when using drilling and turning or milling techniques, for example by securing workpieces safely in the correct position for machining and setting reasonable speeds and feeds. They may sometimes require support from the assessor to ensure that the positional and dynamic parameters are appropriate during machining.
- Set up and carry out drilling and turning or milling machining processes with some skill. They will handle drilling and turning or milling tools, equipment and work-holding devices to machine two workpieces, but may appear hesitant and lack confidence at times. For one of the workpieces, the quality requirements may not be met, for example there may be dimensions outside of required tolerances. The second of the two workpieces will meet the stated quality requirements.
- Carry out quality checks during and after the production of the machined workpieces. They will generate quality records to evidence the quality checks carried out. They may not always carry out relevant and accurate quality checks at appropriate times during production of the workpieces and may fail to recognise the significance of the information provided, for example they make take an inaccurate micrometer reading that shows a dimension that is larger than the previous one leading to the next cut being too deep.
- Demonstrate compliance with safe working practices throughout all of the machining activities.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 9: Engineering Design
- Unit 11: Welding
- Unit 15: Engineering Marking Out.

### Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into industrial machining techniques, the continued importance of drilling, turning and milling to a range of engineering sectors, the importance of safety in machining, the importance of quality checks on workpieces and the need to maintain accurate quality records
- documentation, such as a range of suitable engineering drawings and associated workpieces
- work experience, which will allow learners to become familiar with industrial machining techniques and the typical industrial environments in which they are used. The nature of the knowledge and skills being developed in this unit mean that it is particularly suited to incorporating a period of work experience. Learners could, for example, shadow an inspector when carrying out quality checks on machined parts
- a machine operator or supervisor, to support practical lessons and to provide feedback and developmental advice to learners as their skills develop. This would help to ensure that the machining techniques are taught effectively and mirror those in current use in industry.

# Unit 9: Engineering Design

Level: **2**

Unit type: **Internal**

Guided learning hours: **60**

## Unit in brief

Learners will produce Product Design Specifications (PDS) for engineered products from customer design briefs and generate initial design proposals and solutions.

## Unit introduction

Have you ever wondered how complex engineered products, made using a variety of technologies and techniques, can work so effectively? The answer is because of good design. Engineering designers often work in teams, with different members of the team adding their individual expertise to the development process. This is not always the case, however, and some designs can start with just one person coming up with a good idea and developing it into an innovative product – for example, design entrepreneurs such as Sir Trevor Bayliss and Sir James Dyson.

In this unit you will learn about the factors that influence the design of engineered products. You will also interpret a customer brief in order to generate a Product Design Specification. The PDS is a critical document, outlining all the key requirements that an engineered product should comply with. You will then use the customer brief and the PDS as a basis for producing initial design proposals, which you will generate using creative methods and graphical techniques. Having decided upon the best proposal, you will use appropriate presentation and communication techniques to produce and provide all the details of the chosen solution, ensuring that it meets all of the requirements of the customer brief and the PDS.

## Learning aims

In this unit you will:

**A** Investigate factors that influence the design of engineered products

**B** Develop product design specifications (PDS) for engineered products from customer briefs

**C** Develop design proposals and solutions for engineered products meeting customer briefs and PDS requirements.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate factors that influence the design of engineered products | **A1** Design influences<br>**A2** Engineered products | A report based on successful and unsuccessful engineering products, detailing the influence of a range of internal and external factors that affected the design process such as customer needs and legislation. Annotated diagrams/images should support the evidence. |
| **B** Develop product design specifications (PDS) for engineered products from customer briefs | **B1** Interpreting the customer brief<br>**B2** Requirements of a PDS | A practical activity based on a given client brief, involving the planning of a PDS, creating design proposals, and a design solution.<br>The assessment evidence will include a portfolio of research, thinking techniques, and decision-making strategies, three initial design proposals, and the final design proposals, in a series of sketches and drawings. |
| **C** Develop design proposals and solutions for engineered products meeting customer briefs and PDS requirements | **C1** Initial design proposals<br>**C2** Using graphical techniques<br>**C3** Design solutions | |



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# Content

## Learning aim A: Investigate factors that influence the design of engineered products

### A1 Design influences

The factors that influence the design of engineered products, including:

- internal factors
  - how market research informs the design process
  - what creates demand for products
  - product lifecycle
  - manufacture – choice of materials, manufacturing and assembly techniques
  - assembly – ease of part placement, fitment time, access, reduction in parts
  - ensuring designs are meeting customer needs.
- external factors
  - the effects of competition
  - changing customer requirements
  - technology push and innovation
  - environmental reasons
  - national/international legislation/laws, regulations and standards.

### A2 Engineered products

- Unsuccessful engineered products, e.g.
  - Sinclair's C5
  - Barnes and Noble The Nook
  - Amazon's Fire phone
  - HD DVD
  - Sony Betamax
  - Google glasses.
- Successful engineered products, e.g.
  - Apple iPad
  - Fitbit
  - sports shoes
  - Velcro
  - WD-40®
  - bubble wrap
  - aircraft jet engines.

## Learning aim B: Develop product design specifications (PDS) for engineered products from customer briefs

### B1 Interpreting the customer brief

Extracting information from customer briefs, including the key issues, constraints, opportunities and requirements.

- Physical requirements:
  - styling/aesthetics – the appearance and appeal of the product
  - size – the approximate size in three dimensions
  - potential materials – the types of material that might be suitable for different parts of the product
  - scale of production – quantity required, use of mass or batch production.

- Performance requirements:
  - function – where and what the product will be used for
  - environment versus expected operating conditions for the product
  - performance – how well the product has to perform.
- Market requirements:
  - intended markets – who might use the product
  - competition – with other similar products.

### B2 Requirements of a PDS

Interpreting, anticipating and defining economic and detailed performance and technical requirements based on a customer brief, including:

- physical dimensions
- weight restrictions
- aesthetics
- materials
- ergonomics
- safety and testing requirements
- product functions
- expected performance criteria
- compliance, legislation, regulations and operating standards
- economic requirements
- sustainability
- product life and end-of-life disposal
- production quantities (custom built, modification to an existing product, small batch, large volume)
- maintenance requirements
- reliability and product support
- potential future development (additional products, services, customer requirements).

## Learning aim C: Develop design proposals and solutions for engineered products meeting customer briefs and PDS requirements

### C1 Initial design proposals

Methods of generating ideas and proposed design solutions, including:

- researching existing products
- using group and individual creative thinking techniques
- using evaluation techniques
- using decision-making strategies, such as flow charts, thought showers, mind mapping, decision trees, comparison matrices.

### C2 Using graphical techniques

Producing design sketches using drawing techniques, including:

- freehand
- tracing
- isometric
- oblique
- orthographic
- perspective
- explosions
- cut and paste
- Computer-aided Design (CAD).

Using annotations to show how initial design proposals meet the requirements of a customer brief and a PDS.

### C3 Design solutions

Developing initial design proposals into chosen design solutions and communicating them, including:

- using formal 2D and 3D drawing techniques, such as detail drawings, assembly drawings, general arrangement drawings, circuit diagrams, flow diagrams, schematic diagrams, CAD drawings
- design models, such as physical, CAD, rapid prototyping
- use of relevant international standards and drawing conventions
- selection of materials
- selection of manufacturing techniques
- producing cost estimates
- generating quality requirements
- incorporating legislation and design standards
- production of a design report that includes technical details, such as how the chosen solution meets the requirements of a customer brief and a PDS, design calculations, specific manufacturing requirements.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Investigate factors that influence the design of engineered products</td><td rowspan="2">A.D1 Evaluate why specific internal and external factors have had the greatest influence on the design of an engineered product.</td></tr>
<tr><td>A.P1 Describe internal and external factors that influence the design of an engineered product.</td><td>A.M1 Explain how internal and external factors have influenced the design of an engineered product.</td></tr>
<tr><td colspan="2">Learning aim B: Develop product design specifications (PDS) for engineered products from customer briefs</td><td rowspan="4">BC.D2 Refine initial design proposals and a chosen solution to meet all of the requirements of a customer brief and an effective PDS.</td></tr>
<tr><td>B.P2 Identify the important requirements from a customer brief.<br>B.P3 Produce a PDS to meet some of the requirements of a customer brief.</td><td>B.M2 Produce a detailed PDS to meet most of the requirements of a customer brief.</td></tr>
<tr><td colspan="2">Learning aim C: Develop design proposals and solutions for engineered products meeting customer briefs and PDS requirements</td></tr>
<tr><td>C.P4 Present suitable initial design proposals that meet some of the requirements of a customer brief and a PDS.<br>C.P5 Present a suitable chosen solution that meets some of the requirements of a customer brief and a PDS.</td><td>C.M3 Present suitable and detailed initial design proposals that meet most the requirements of a customer brief and a PDS.<br>C.M4 Present a suitable and detailed chosen solution that meets most of the requirements of a customer brief and a PDS.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aims: B and C (B.P2, B.P3, C.P4, C.P5, B.M2, C.M3, C.M4, BC.D2)

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# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a range of case studies/engineered products to investigate internal/external factors that have influenced their design
- a range of customer briefs/requirements
- manual sketching/drawing equipment and 2D/3D CAD software
- reference materials such as extracts and illustrations from appropriate international drawing standards and conventions, information about the physical and mechanical properties of materials, material suppliers' catalogues, relevant legislation and design standards etc.

## Essential information for assessment decisions

## Learning aim A

The assessment activity for Learning aim A must include:

- a range of internal and external factors that influenced the design of an engineered product, a range is a minimum of three
- the external factors, environmental reasons, or laws
- the internal factor, meeting customer needs
- successful and unsuccessful engineered products as stated in the *Content* for Learning aim A, or different suitable successful and unsuccessful engineered product
- evidence from one successful and one unsuccessful engineered product or relate internal and external factors to several different successful and unsuccessful engineered products
- annotated diagrams and images of the engineering products to support their arguments.

**For Distinction standard**, learners will:

- Provide an evaluation that considers a total of 3 internal and 3 external factors that had the greatest influence on the design of a successful and an unsuccessful engineering product.
- Accurately identify and consider why some engineered products have been successful and others have been unsuccessful, and which factors had the greatest influence on the design. For example, how marketing affects customer awareness; a failed marketing campaign, where the consumer market and media showed no faith in the product such as Sinclair's C5.
- Accurately identify and consider the impact of internal and external factors in terms of engineering products over time or their life cycle, and what factors had the greatest influence on the design. Consider why some were successful, and some were not. For example, products life cycles that are considered to exceed or be below consumer demand.
- Accurately identify and consider the changes in design, for successful and unsuccessful engineered products, due to customer needs and innovation, and what factors had the greatest influence on the design. For example, some products come to market and never change, whilst others go through many iterations, such as an Apple iPad.

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- Accurately identify and consider the reasons why internal and external factors affect design of engineering products as customer opinions change over time, why some are successful, and some are not. For example, the demise of CD players.
- Accurately identify and consider the changes in design for successful and unsuccessful engineered products due to environmental and legislation changes, for example how environmental or legislation has affected established products.

**For Merit standard**, learners will:

- Provide an explanation that considers a total of two internal and two external factors that have influenced the design of successful or unsuccessful engineering product.
- Identify and consider the internal and external factors that have influenced the design of the engineered product. For example, how designers meet the demands of consumer needs.
- Identify and consider the impact of internal and external factors in terms of engineering product life cycles. For example, how marketing affects sales of sport shoes.
- Identify and consider the changes in the design of engineered products, due to manufacturer competition. For example, an overseas competitor selling products cheaper.
- Identify and consider the changes in design for engineered products due to environmental and legislation changes. For example, the reduction in plastic drinking straws, now being manufactured from paper.

**For Pass standard**, learners will:

- Provide a description that considers a total of three internal and external factors which have an influence on the design of successful or unsuccessful engineering product.
- Provide a written description for the factors that contribute to the design of the engineered product. For example, no marketing being undertaken prior to the product launch.
- Provide a written description for the factors of engineering products over time or their life cycle. For example, how companies ensure that designs continuously meet consumer needs, or how marketing affects sales of GPS sport watches.
- Provide a written description for the factors of engineering products due to environmental and legislation changes. For example, the reduction in noise from aircraft jet engines.

## Learning aims B and C

The assessment activity for Learning aims B and C must include:

- Learners must be provided with a customer brief covering approximate size, approximate production volume required and any function and performance requirements.

- The customer brief could be focused on one of the following engineered products (this list is not definitive or exhaustive but is provided to give an indication of the level of complexity required):
    - burglar alarm
    - machine vice
    - hair dryer
    - wire strippers
    - adjustable spanner
    - portable battery powered drill
    - doorbell.
- Learner must provide a PDS that covers the economic, performance and technical requirements from the client brief.
- Learners must produce at least three initial design proposals.
- Initial design proposals will be sketches that are fully annotated to show how they meet the PDS and client brief.
- The final design proposal must be a detailed technical drawing or detailed design sketches, showing all necessary views, dimensioned, within a drawing frame.
- Final designs will be created as drawings or sketches in orthographic projection or 2D CAD. Isometric drawings can support the orthographic drawing.
- Final designs will be supported by written notes to show how they meets the PDS and client brief.
- Learners will present an annotated portfolio, including PDS, initial design proposals, research, thinking techniques, and decision-making strategies, and the final design solution.

**For Distinction standard**, learners will:

- create a new design proposal including a report, sketches, and drawings to show the refinements and show improvements which considers a range of ideas and options for physical and functional requirements. For example, refinements to the design solution and PDS might improve the grip on a powered hand tool that may not ergonomically suit a range of people.
- create a PDS that shows an accurate interpretation of the technical, economic and performance requirements. For example, dimensions will be accurate and ergonomically appropriate for the intended market.
- provide a report including sketches and drawings that identifies product life and product disposal options, reasonable production volumes and product reliability for a given engineered product. For example, end of life disposal will be considered, items such as polymers will be considered for recycling only when appropriate to do so. Many thermosetting plastics are not suitable for recycling.
- develop the product proposal through appropriate creative techniques such as flow diagrams, thought showers and mind mapping, that are well presented and accurately represent the proposals.
- create a solution and a specification to present and prepare their final design solution, using detailed design sketches, an accurate orthographic engineering drawing or a CAD drawing. For example, engineering drawings will be laid out and dimensioned correctly.

**For Merit standard**, learners will:

- create a final design proposal including a report, sketches, and drawings that show suitable and detailed improvements which consider a range of ideas and options for physical and functional requirements. For example, learners will produce a range of initial designs and then a final design solution that is adjustable to meet different segments of the market.
- create a PDS that shows a suitable and detailed interpretation of the technical, economic and performance requirements. For example, most dimensions will be accurate and with some consideration to ergonomics for the intended market.
- provide a report including sketches and drawings that provides a suitable and detailed product life, product disposal options, production volumes and product reliability for a given engineered product. For example end of life disposal will be considered and items such as ferrous metals will be considered for recycling.
- develop the product proposal through appropriate creative techniques such as flow diagrams, thought showers and mind mapping, that are suitable and detailed to represent the proposals.
- create a solution and a specification to present and prepare their final design solution, using design sketches, an orthographic engineering drawing or a CAD drawing. For example, engineering drawings will be laid out with some views unaligned, and most dimensions added.

**For Pass standard**, learners will:

- create a final design proposal including a report, PDS, sketches, and an engineering drawing that shows suitable physical and functional requirements. For example, learners will produce a range of initial designs and then a final design solution with suitable enhancements for older people.
- create a PDS that shows a suitable interpretation of the technical, economic and performance requirements. For example, some dimensions will be given with limited accuracy.
- provide a report including sketches and drawings that suitably identifies product life and product disposal options, production volumes and product reliability for a given engineered product. For example end of life disposability will only be partially considered, items such as metals might be given little consideration for recycling.
- Develop the product proposal through appropriate creative techniques such as flow diagrams, thought showers and mind mapping, that are suitable and presented to represent some of the proposals.
- create a solution and a specification to present and prepare their final design solution, using design sketches, an engineering drawing, or a CAD drawing. For example, engineering drawings/sketches will show main features with some dimensions added.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 10: Engineering Fitting and Assembly
- Unit 13: Operations and Maintenance of Mechanical Systems and Components.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, to provide examples of how design processes have been used to develop successful engineered products
- visits to design workshops, to observe real-life working practices and procedures in action
- visits to design exhibitions, to see engineered products that have been newly developed
- work experience, which will allow learners to become much more familiar with industrial engineering environments and the way they are set-up to support creativity and innovation.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Using iteration and appropriate approaches to solve engineering design problems.

### Managing information

- Interpreting customer briefs in order to develop design proposals.

### Self-management and development

- Effectively self-managing the preparation and carrying out of design activities.



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# Unit 10: Engineering Fitting and Assembly

Level: **2**
Unit type: **Internal**
Guided learning hours: **30**

## Unit in brief

Learners will use methods and tools safely to assemble and check the quality of assembled engineering equipment and components.

## Unit introduction

Have you ever wondered how motor racing teams prepare their cars for competition? The accurate assembly of many different components before a race requires the skills of a range of experienced engineers. Many engineering activities rely on the correct arrangement of components to carry out specific functions. This unit aims to give you the knowledge and skills needed to carry out a range of relevant assembly activities on engineering equipment – for example, the assembly/sub-assembly and fitting of mechanical, electrical/electronic, fluid power and pipework components or systems in accordance with approved procedures.

You will use a range of assembly tools and equipment, and check that they are in a safe and usable condition. When assembling components, you will need to work to given procedures and check that you have the appropriate information and tools to complete the activity. Having followed the assembly instructions, you will be expected to make sure that the components are positioned and aligned correctly. You will also need to check that moving parts have the correct working clearances, that all fasteners are tightened, that wiring or piping is connected correctly and that the assembly functions according to the specification.

This unit can be applied within a specific area such as fluid power equipment, but it is more likely that a range of specialisms will be covered in any one assembly activity. For example, the fitting of a fluid pump may also require mechanical, electrical and pipework knowledge and skills. You will need to have a basic understanding of the components being assembled, their functions and their expected operating parameters.

Safe working practices and good housekeeping will be a theme that runs throughout the unit. You will be expected to demonstrate an understanding of the responsibility you have for your own safety and that of others in the workplace.

## Learning aims

In this unit you will:

**A** Investigate tools, equipment and measuring instruments to check the quality of assembled engineering equipment

**B** Safely assemble components to engineering equipment.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate tools, equipment and measuring instruments to check the quality of assembled engineering equipment | **A1** Inspecting fitness for service<br>**A2** Tools, equipment and measuring instruments<br>**A3** Assembled engineering equipment | A report with annotated images/diagrams/photographs detailing the selection and use of a range of tools, equipment and measuring instruments to accurately check the quality of two different types of assembled engineering equipment. |
| **B** Safely assemble components to engineering equipment | **B1** Assembly methods and tools<br>**B2** Connect/fit components<br>**B3** Quality and accuracy | A practical activity involving the selection and use of tools and equipment to complete two assembly activities safely.<br>A logbook containing annotated images/diagrams/photographs detailing the selection of components and the safe use of a range of tools, equipment and techniques to accurately connect the components to two examples of engineering equipment. Completed quality control records will also be included along with learner observation records. |

# Content

## Learning aim A: Investigate tools, equipment and measuring instruments to check the quality of assembled engineering equipment

### A1 Inspecting fitness for service

Inspecting tools, equipment and measuring instruments to ensure they are fit to use when carrying out a quality check on an assembled engineering piece of equipment:

- appropriate to assembly activity – following the drawing guidance, job instructions, assembly procedures
- health and safety considerations – personal protective equipment and clothing, safe working methods, relevant regulations and guidance, e.g. use of hazardous material data sheets, risk assessment
- permitted operating range: e.g. safe working load, voltage/current range, torque, range and type of dimensions.

### A2 Tools, equipment and measuring instruments

General safe working practices while using tools, equipment and instruments:

- hand tools, e.g. hacksaws, files, spanners, screwdrivers, wrenches, sockets, crimping tools, side cutters, wire strippers
- power tools, e.g. drills, soldering irons, air tools
- equipment, e.g. for lifting and moving, jigs, fixtures, supports, wire looms
- measuring instruments, e.g. rule, tape measure, micrometers, gauges, dial test indicators, multimeters, pressure meters
- personal protective equipment (PPE).

### A3 Assembled engineering equipment

Working on engineering equipment, such as a vehicle sub-system like brake callipers or a domestic appliance like a washing machine, with a range of components to carry out quality checks.

- Quality checks: completeness, alignment, size, positional accuracy, component security, damaged components or contamination/foreign objects.
- Engineering equipment, such as car engines, computers or bicycles, that have a range of components e.g.:
  - electrical/electronic, correct inputs/outputs, electrical continuity
  - pipework, correct direction and flow, component quality (pipe free from creases or ripples)
  - fluid power, function, leak and pressure testing, electrical continuity, pipework free from ripples or creases
  - sub-assemblies, function, freedom of movement, orientation, operating/working clearances, bearing end float.

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## Learning aim B: Safely assemble components to engineering equipment

### B1 Assembly methods and tools

Be able to perform a range of assembly methods on engineering equipment and use suitable tools including:

- fitting, e.g. filing, scraping, lapping, polishing, blue bedding of components, shimming, packing, use of expansion/contraction methods
- securing, e.g. fasteners, threaded devices, bolt locking methods, riveting, soldering, brazing, sealants, adhesives
- use of assembly aids and equipment, e.g. work-holding devices, jigs, fixtures, supports, lifting and moving equipment, rollers, wedges
- tools, e.g. drills, soldering irons, reamers, press tools, hacksaws, files, spanners, screwdrivers, wrenches, sockets, crimping tools, torque wrench, alignment tools, tube cutter
- working within specified timeframes, estimation of time to complete activity, working to set times
- maintaining safe working environment, using appropriate and approved assembly techniques at all times, work area housekeeping, risk assessments.

Carrying out assembly activities:

- sub-assemblies or assemblies, e.g. panel, support framework, casings, fluid power, simple electrical circuit, component kits.

### B2 Connect/fit components

Be able to connect/fit components to engineering equipment.

- Pipework:
  - control components, e.g. valves, taps, regulators
  - storage devices, e.g. tanks and reservoirs
  - monitoring equipment, e.g. sensors, meters, gauges
  - fluid distribution equipment, e.g. motors, pumps
  - use of pipe materials, e.g. steel, copper, plastic, flexible hoses
  - joining methods, e.g. compression joints, push-fit, brazing, soldering, cementing, bonding
  - connectors, e.g. straight, reduction, elbows, flanges.
- Electrical/electronic:
  - components, e.g. conduit, trunking, tray type table enclosures, plugs and sockets, sensors, motors, transformers, relays, solenoids, switches, electronic modular units, instrumentation units
  - techniques, e.g. routing cables and wires, mounting/securing components, cable fixings and fasteners, terminating and joining cables/wires using screwed/clamped/soldered/crimped connections
  - use of cable protection devices, sleeving, grommets, cable glands.
- Fluid power:
  - components, e.g. motors, pumps, compressors, intensifiers, filters, lubricators, separation units, reservoirs, accumulators, sensors, meters, gauges, indicators
  - pipework and connection devices, e.g. manifolds, couplings, laying pipework/cabling/wires
  - control components, valves, actuators, cylinders, regulators.

### B3 Quality and accuracy

Checking compliance and achieving quality and accuracy through a range of standards and information including:

- quality checks, e.g. setting working clearance, torque settings, alignment, balancing
- national and international standards, relevant national standards, International Organization for Standardization (ISO)
- design standards, customer standards and requirements, company standards and procedures
- specified instructions, e.g. specific system requirements, operational manuals, manufacturers' instructions, engineering drawings, assembly drawings.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate tools, equipment and measuring instruments to check the quality of assembled engineering equipment** | | |
| **A.P1** Describe the tools, equipment and measuring instruments to be used when checking the quality of different types of assembled engineering equipment.<br>**A.P2** Select, inspect and use tools, equipment and measuring instruments to check the quality of different types of assembled engineering equipment. | **A.M1** Justify the use of specific tools, equipment and measuring instruments when checking the quality of different types of assembled engineering equipment.<br>**A.M2** Inspect and use tools, equipment and measuring instruments with accuracy to check the quality of different types of assembled engineering equipment. | **A.D1** Evaluate the inspection and use of specific tools, equipment and measuring instruments when checking, with accuracy, the quality of different types of assembled engineering equipment. |
| **Learning aim B: Safely assemble components to engineering equipment** | | |
| **B.P3** Select and use methods and tools to carry out assembly activities.<br>**B.P4** Safely select and connect/fit components to engineering equipment.<br>**B.P5** Check assembled components for quality and accuracy. | **B.M3** Safely and accurately connect/fit components to engineering equipment, showing a good level of skill. | **B.D2** Safely and accurately connect/fit components to engineering equipment, showing a high level of adaptability and skill. |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim: B (B.P3, B.P4, B.P5, B.M3, B.D2)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a range of assembled engineering equipment and components to enable them to carry out the practical aspects of this unit as defined by the content and assessment criteria
- a workshop environment and the range of tools, equipment and measuring instruments required to carry out the practical aspects of this unit as defined by the content and assessment criteria
- engineering drawings, circuit diagrams and technical information for the assemblies to be inspected. These should include dimensional details, such as tolerances, and details of pressures, voltages, currents, etc. for fluid and electrical assemblies.

### Essential information for assessment decisions

### Learning aim A

**For Distinction standard**, learners will:

- Evaluate at least two specific tools, two specific pieces of equipment and two specific measuring instruments that are used for inspecting the quality of two different types of assembled engineering equipment. The evaluation will provide precise and correct reasons why the chosen tools, equipment and measuring instruments are the most appropriate by referring to the features of both of the examples of assembled engineering equipment and potential alternatives. Learners will give reasons why these alternatives were considered less suitable, for example why a socket and wrench is preferable to an adjustable wrench for adjusting bolts.
- Select the most appropriate tools, equipment and measuring instruments for checking the quality of two different types of assembled engineering equipment.
- Check the fitness for service and then safely and accurately use the selected tools, equipment and measuring instruments to inspect the quality of two different types of assembled engineering equipment against provided drawings and technical information.

**For Merit standard**, learners will:

- Justify the use of at least two specific tools, two specific pieces of equipment and two specific measuring instruments for inspecting the quality of two different types of assembled engineering equipment. The justification will provide accurate reasons why the specific tools, equipment and measuring instruments are appropriate for the inspection task, for example the use of a voltmeter to check continuity in a vehicle lighting system.
- Select suitable tools, equipment and measuring instruments for checking the quality of two different types of assembled engineering equipment.
- Check the fitness for service and then safely and accurately use the selected tools, equipment and measuring instruments to inspect the quality of two different types of assembled engineering equipment, for example one mechanical sub-assembly and one pipework assembly.

**For Pass standard**, learners will:

- Describe at least two tools, two pieces of equipment and two measuring instruments to be used for checking the quality of two different types of assembled engineering equipment. The tools, equipment and measuring instruments will be mostly suitable, for example they might consider the resources needed to inspect for freedom of movement of a steering sub- assembly but might omit operating clearances.
- Select tools, equipment and measuring instruments for checking the quality of two different types of assembled engineering equipment. They may not be the most effective or efficient, for example they might use a steel rule rather than a micrometer for measuring the diameter of a piece of pipe.
- Check the fitness for service and then safely use selected tools, equipment and measuring instruments to inspect the quality of two different types of assembled engineering equipment, for example a vehicle cooling system.

## Learning aim B

**For Distinction standard**, learners will:

- Identify and select the most appropriate components required to connect or fit components to two different examples of engineering equipment, for example one pipework system and one electrical/electronic system. The selections will be fully appropriate to meet provided instructions and standards.
- Select the most appropriate tools, methods and techniques to accurately carry out the two assembly tasks safely and accurately. The tools, methods and techniques should allow for the necessary levels of accuracy to be achieved in full.
- Carry out an appropriate range of quality and accuracy checks on at least one of the completed assemblies. Records of the quality checks will be complete and record outcomes in detail.
- Demonstrate compliance with safe working practices throughout all of the assembly activities and show adaptability in the event of unforeseen situations such as incompatible electrical connectors.

**For Merit standard**, learners will:

- Identify and select suitable components required to connect or fit components to two different examples of engineering equipment, for example one pipework system and one electrical/electronic system. The selections will be in line with provided instructions and standards, for example selecting an appropriate size and type of mechanical fixing based on technical information provided in an assembly drawing.
- Select suitable tools, methods and techniques to accurately carry out the two assembly tasks in a safe manner. The tools, methods and techniques should allow for the necessary levels of accuracy to be met, however they may not be the most efficient available to them, for example they might choose to use a hacksaw to cut a length of tube rather than a tube cutter.
- Carry out quality and accuracy checks on at least one of the completed assemblies using suitable processes. Records of the quality checks will be complete but may be lacking in precision.
- Demonstrate compliance with safe working practices throughout all of the assembly activities.

**For Pass standard**, learners will:

- Identify and select components required to connect or fit at least one component to two different examples of engineering equipment, for example one pipework system and one electrical/electronic system. The selections will be in line with provided instructions and standards, for example selecting a switch with a suitable voltage and current rating based on the provided technical information.
- Select tools, methods and techniques to carry out assembly tasks in a safe manner. The tools, methods and techniques may not be the most effective or efficient available to them, for example they might choose to use side cutters to strip a wire rather than wire strippers.
- Carry out quality and accuracy checks on at least one of the completed assemblies. They will need to check the assembly against the provided instructions and standards and produce records of the quality checks they carried out, although these may be lacking in precision and have some omissions.
- Demonstrate compliance with safe working practices throughout all of the assembly activities.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 11: Welding
- Unit 14: Fabrication Techniques
- Unit 15: Engineering Marking Out
- Unit 16: Application of Quality Control and Measurement in Engineering
- Unit 26: Robotics
- Unit 31: Vehicle Maintenance Techniques.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into assembly techniques used in industry, the importance of safety when completing assembly activities, the importance of quality checks on completed assemblies and the need to maintain accurate quality records
- documentation, such as a range of suitable engineering drawings and associated work instructions
- work experience, which will allow learners to become familiar with assembly techniques used in industry and the typical engineering products in which they are used.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate methods and tools to complete an assembly activity and to inspect assembled components.

### Managing information

- Collecting, recording and interpreting quality data.

### Self-management and development

- Development of practical skills relating to assembly processes will be self-managed by learners.

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# Unit 11: Welding

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will plan for and produce MIG and MMA welded joints and perform non-destructive and destructive tests on given sample welds.

## Unit introduction

Welding is the permanent joining of metal using localised heat to melt and fuse the parts together. In this practical unit, you will investigate two different types of welding process that use an electric arc to generate the high temperatures required to form a welded joint. Safety when welding is vital and you will look at the hazards encountered when welding, the risks of injury to yourself or others and the ways in which these risks can be controlled. After investigating the tools, equipment and consumables also involved, you will put theory into practice by planning for making and then making some welded joints. Through practical exercises you will learn how to select and set up the equipment, as well as how to prepare the materials to be joined. When your skills have developed sufficiently you will be asked to produce a series of welded joints that will form part of your assessment.

In this unit, you will also look at how to determine the quality of a welded joint by identifying defects on the surface or inside the weld itself. You will get the opportunity to carry out both non-destructive and destructive testing on given sample welds.

As an engineer, it is important to understand welding processes and how weld defects can be detected and avoided, meaning that this unit helps to prepare you for employment or for further study in engineering.

## Learning aims

In this unit you will:

**A** Plan for safe welding operations

**B** Carry out welding operations safely

**C** Test welded joints safely.

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## Summary of unit

<table>
<tr><th>Learning aim</th><th>Key content areas</th><th>Assessment approach</th></tr>
<tr><td>A Plan for safe welding operations</td><td>A1 Welding processes<br>A2 Consumables<br>A3 Tools, equipment and information sources<br>A4 Working safely</td><td rowspan="2">Evidence could be presented as annotated photographs and brief notes.<br>Written notes should be supported by diagrams/ images.<br>Observation records would support this evidence.</td></tr>
<tr><td>B Carry out welding operations safely</td><td>B1 Safety<br>B2 Making welded joints</td></tr>
<tr><td>C Test welded joints safely</td><td>C1 Weld testing<br>C2 Safety</td><td>Results recorded as notes and annotated diagrams/ images. Observation records would support this evidence.</td></tr>
</table>

# Content

## Learning aim A: Plan for safe welding operations

### A1 Welding processes

Types of process used when welding metals, including:

- MIG (Metal Inert Gas)
- MMA (Manual Metal Arc).

### A2 Consumables

Consumables relevant to the welding processes, including:

- MIG – wire, inert gas (such as argon), welding tips
- MMA – welding rods.

### A3 Tools, equipment and information sources

Tools and equipment, including:

- basic hand tools such as side cutters, chipping hammer, wire brush
- work holding devices such as C-clamp, locking pliers, sheet clamp locking pliers, magnetic clamps, welding bench
- welding equipment such as cables, hoses, torches, welding tips, shrouds, electrode holders, gas bottles, regulator.

Set-up of welding equipment, including:

- equipment, such as cables, weld return lead and clamp, electrode holders, inert gas supplies, regulators, safety devices
- welding parameters, such as setting and adjusting gas pressures/flow rates, voltage, amperage, wire feed rate.

Information sources, including:

- safety instructions, job instructions, engineering drawings, weld procedure, record sheets, health and safety risk assessments, safe operating procedures.

### A4 Working safely

Safety awareness while carrying out welding processes in a working environment, including:

- hazards and risks, such as weld spatter, sparks, UV radiation, extreme heat, fumes
- control measures.

## Learning aim B: Carry out welding operations safely

### B1 Safety

Keeping safe in a welding environment, including:

- fire precautions and procedures
- manual handling, such as moving materials, equipment, gas cylinders
- pre-work condition checks, such as on pipework, welding tips, leads
- keeping a clean and tidy work area
- using local exhaust ventilation and welding screens
- personal protective equipment (PPE), such as welding masks, gloves, aprons, eye protection
- closing down equipment safely and leaving in a safe condition.

### B2 Making welded joints

Preparation of materials to be joined, including:

- checking materials are free from excessive contamination, such as rust, oil, grease, dirt
- material edge preparation, such as flat, square, bevel, chamfer, groove
- material positioning and work holding, such as setting position, alignment, gapping, clamps, jigs and fixtures.

Producing welded joints in steel, including:

- material forms, such as plate, section, pipe/tube
- weld type, such as tack, butt, fillet
- starting the weld, such as striking the arc, adjusting/controlling the arc, feeding the weld pool, refining welding parameters
- welding positions, such as flat/horizontal, vertical downwards, vertical upwards.

Quality checks including:

- dimensional, such as positional accuracy, angular alignment, size, profile of weld, distortion, penetration.

## Learning aim C: Test welded joints safely

### C1 Weld testing

Non-destructive tests including:

- visual inspection for surface defects such as poor uniformity, misalignment, poor penetration, inappropriate fillet size, porosity, slag inclusions, parent metal spatter, arcing or chipping marks
- specialist tests for weld defects such as dye penetrant, fluorescent particle, magnetic particle
- weld defects
- completion of inspection and test records.

Destructive tests including:

- cutting a specimen section of weld using tools such as a hacksaw, power saw, abrasive cutting disc
- specimen preparation such as removing slag/spatter/surface irregularities, cleaning, degreasing, polishing, making saw cuts in welds
- tests for weld defects such as the nick break (fracture) test, bend test
- weld defects
- completion of test records.

### C2 Safety

Safety awareness when testing welded joints:

- safe handling and use of tools, equipment and chemicals such as cutting equipment, cleaning/degreasing chemicals
- personal protective equipment (PPE) such as eye protection, face protection, gloves
- safety instructions, test procedures, record sheets, health and safety risk assessments, safe operating procedures.



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## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Plan for safe welding operations** | | **AB.D1** Produce accurate butt and fillet welds using MIG and MMA safely and effectively, following a comprehensive plan and refining the initial set-up during the process of welding. |
| **A.P1** Plan for the safe production of butt and fillet welds using MIG and MMA. | **A.M1** Plan in detail for the safe production of butt and fillet welds using MIG and MMA. | |
| **Learning aim B: Carry out welding operations safely** | | |
| **B.P2** Set up MIG and MMA safely for welding, including consumables, material preparation and work holding.<br>**B.P3** Produce butt and fillet welds using MIG and MMA safely. | **B.M2** Produce accurate butt and fillet welds using MIG and MMA safely, using an appropriate initial set-up. | |
| **Learning aim C: Test welded joints safely** | | **C.D2** Evaluate the quality of a welded joint using the results from a methodical and accurate visual inspection, destructive test and non-destructive test. |
| **C.P4** Perform a visual inspection of a welded joint, recording the results.<br>**C.P5** Perform a specialist non-destructive test on a welded joint safely, recording the results.<br>**C.P6** Perform a destructive test on a welded joint safely, recording the results. | **C.M3** Analyse the quality of a welded joint using the results from a methodical visual inspection, destructive test and non-destructive test. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aim: C (C.P4, C.P5, C.P6, C.M3, C.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- MIG and MMA welding equipment and associated tools and other resources as per the content section
- equipment to carry out at least one form of non-destructive testing (dye penetrant, fluorescent particle or magnetic particle)
- a selection of sample welds that contain one or more defects, and these defects must be detectable using one or more of the following techniques: visual inspection, non-destructive or destructive testing.

## Essential information for assessment decisions

## Learning aims A and B

**For Distinction standard**, learners will:

- Produce a comprehensive plan for welding butt and fillet welds using both MIG and MMA welding equipment. This will include detailed and complete information on safe working practices, PPE, equipment set-up and parameters, consumables, material preparation requirements and work holding.
- Refine initially appropriate set-up and welding parameters to make welding easier, more accurate or more effective. This might include repositioning work and work-holding clamps to improve access, clearance or accuracy or increasing the weld current to achieve more effective weld penetration.
- Produce butt and fillet welds using both MIG and MMA welding equipment safely, accurately and effectively. Accurate joints will be aligned with a tolerance of +/- 3° from the required angle. Effective welds will be along the full length of the joint in a single bead and have visible indications of good penetration on the reverse side of the weld. There will be little or no spatter, arcing or chipping marks on the material surrounding the weld.

**For Merit standard**, learners will:

- Develop a detailed plan for welding butt and fillet welds using both MIG and MMA welding equipment. This will include detailed information covering most of the following topics: safe working practices, PPE, equipment set-up and parameters, consumables, material preparation requirements and work holding.
- Initial set-up and welding parameters will be appropriate to the material thickness and type of weld being planned. This might include suitable work holding and current settings.
- Produce butt and fillet welds using both MIG and MMA welding equipment safely and accurately. Accurate joints will be aligned with a tolerance of +/- 3° from the required angle.
- Welds may not be along the full length of the joint in a single bead and visual indications of good penetration on the reverse side of the weld may be inconsistent. There may be some spatter, arcing or chipping marks on the material surrounding the weld.

**For Pass standard**, learners will:

- Create a plan for welding butt and fillet welds using both MIG and MMA welding equipment. This will include basic information on some of the following topics: safe working practices, PPE, equipment set-up and parameters, consumables, material preparation requirements and work holding.
- Initial set-up and welding parameters may not be wholly appropriate to the material thickness and type of weld being planned. This might include unsuitable work holding or initial current settings.
- Produce butt and fillet welds using both MIG and MMA welding equipment safely.
- Joints will be aligned with a tolerance of +/- 10° from the required angle.
- Welds may be interrupted or discontinuous along the length of the joint and have few visual indications of good penetration on the reverse side of the weld. There may be considerable spatter, arcing or chipping marks on the material surrounding the weld.

### Learning aim C

**For Distinction standard**, learners will:

- Perform a methodical and effective visual inspection, non-destructive test and destructive test on at least one given sample weld. A methodical approach involves the learner following each test procedure carefully and performing all the steps required in the right order. Testing is accurate if the learner identifies all the detectable defects present in the sample weld.
- Use the combined results from methodical and effective testing to evaluate the overall quality of the sample weld. This will include a description of all the defects present in the sample and make suggestions on how these can be avoided.

**For Merit standard**, learners will:

- Perform a methodical visual inspection, non-destructive test and destructive test on at least one given sample weld. A methodical approach involves the learner following each test procedure carefully and performing all the steps required in the right order. However, the learner may identify some but not all of the detectable defects present in the sample weld.
- Use the combined results from methodical testing to analyse the overall quality of the sample weld. This will include a description of the defects detected in the sample weld.

**For Pass standard**, learners will:

- Perform a visual inspection, non-destructive test and destructive test on at least one given sample weld. Their approach may not be methodical and they will record few, if any, of the detectable defects present in the sample weld.



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## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 10: Engineering Fitting and Assembly
- Unit 14: Fabrication Techniques
- Unit 15: Engineering Marking Out
- Unit 16: Application of Quality Control and Measurement in Engineering
- Unit 26: Robotics
- Unit 31: Vehicle Maintenance Techniques.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers
- staff from local engineering and fabrication organisations, with expertise in welding, to deliver technical workshops
- ideas for suitable welding projects.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

- becoming familiar with the properties and characteristics of a range of different materials
- working safely in hazardous environments and ensuring that they and others around them are safe at all times
- reviewing their personal performance when undertaking practical activities within workshops or facilities.

# Unit 12: Business Improvement Techniques

Level: **2**

Unit type: **Internal**

Guided learning hours: **30**

## Unit in brief

Learners will apply business improvement techniques to reduce waste and reorganise an engineering work area.

## Unit introduction

If you work in an engineering organisation you will have a shared responsibility to contribute to improving productivity, which means you need to understand how business improvement techniques are used. Many engineering organisations have a strong culture of continuous improvement and will encourage you to take ownership of improvement activities and to develop working practices that increase efficiency and enhance quality and safety, while at the same time reducing costs.

In this unit, you will investigate and use business improvement techniques that are commonly applied in an engineering workplace. This will include changing business processes in order to reduce waste and reorganising a work area to make it safer and more efficient.

This unit will prepare you for work in the engineering sector by giving you the knowledge, understanding and skills needed to assess and improve your own workplace to make it more efficient and cost-effective.

## Learning aims

In this unit you will:

**A** Implement waste reduction techniques in an engineering workplace

**B** Make improvements to the organisation of an engineering work area using a 5S work area scan.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Implement waste reduction techniques in an engineering workplace | **A1** Analysing a business process<br>**A2** Types of waste<br>**A3** Benefits of reducing waste | An activity involving the mapping of a given business process so that changes can be made to reduce waste.<br>The assessment evidence will include:<br>· flow charts with detailed annotations<br>· a report evaluating the benefits of the changes made. |
| **B** Make improvements to the organisation of an engineering work area using a 5S work area scan | **B1** Implementing 5S work area organisation<br>**B2** Benefits of 5S work area organisation | A practical activity where all aspects of a 5S implementation are conducted in an engineering work area. |

## Content

### Learning aim A: Implement waste reduction techniques in an engineering workplace

#### A1 Analysing a business process

- Creating and analysing business process maps (flow charts).
- Identifying value-added activities, e.g. drilling a hole, fitting a component.
- Identifying non-value-added activities, e.g. changing tooling, moving materials.
- Processes to reduce/eliminate non-value added activities and minimise waste.

#### A2 Types of waste

- Common types of waste found in business processes, to include transport, inventory, motion, waiting, overproduction, overprocessing, defects, underdeveloped skills/unrecognised people potential.

#### A3 Benefits of reducing waste

Benefits of reducing waste, to include:

- reduced cost, e.g. lower production costs, lower transport costs
- improved quality, e.g. fewer defects, less time correcting mistakes
- improved safety, e.g. fewer delays caused by accidents
- improved working practices, e.g. reducing unnecessary operator movement
- improved delivery, e.g. reduced transportation time, reduced lead time
- reduction of waste materials, e.g. reduced scrap rates
- improved resource utilisation, e.g. reduced waiting time, increased efficiency
- improved customer satisfaction, e.g. meeting customer orders on time and to specification.

### Learning aim B: Make improvements to the organisation of an engineering work area using a 5S work area scan

#### B1 Implementing 5S work area organisation

- Use of 5S work area scan checklists before full 5S implementation to identify problems or omissions.
- Stages of implementation of 5S:
  - sort – eliminate whatever is not needed or no longer used
  - straighten – organise whatever remains, having a place for everything and everything in its place
  - shine – clean the work area
  - standardise – schedule regular cleaning and maintenance
  - sustain – continuously review and improve work area organisation.

#### B2 Benefits of 5S work area organisation

Benefits of implementing 5S, to include:

- increased safety, reduction of unnecessary operator movement, improved productivity, increased quality, increased employee sense of involvement and ownership of their working environment, increased morale.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Implement waste reduction techniques in an engineering workplace</td><td rowspan="2">A.D1 Evaluate the benefits gained from reducing waste in a given business process.</td></tr>
<tr><td>A.P1 Identify unnecessary waste by mapping a given business process.<br>A.P2 Reduce waste in a given business process by suggesting improvements.</td><td>A.M1 Reduce waste in a given business process by suggesting improvements based on comprehensive mapping.</td></tr>
<tr><td colspan="2">Learning aim B: Make improvements to the organisation of an engineering work area using a 5S work area scan</td><td rowspan="2">B.D2 Evaluate the benefits gained from the effective implementation of 5S in an engineering work area.</td></tr>
<tr><td>B.P3 Carry out a 5S engineering work area scan using an appropriate checklist.<br>B.P4 Implement 5S recommendations in an engineering work area.</td><td>B.M2 Implement 5S recommendations effectively in an engineering work area based on a comprehensive 5S engineering work area scan.</td></tr>
</table>



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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a range of case studies giving examples of business processes for the manufacture of an engineering product or the delivery of an engineering service
- an engineering work area where a 5S implementation can be carried out.

## Essential information for assessment decisions

The assessment activity for learning aim A must allow learners the opportunity to map a given business process for the manufacture of an engineering product or the delivery of an engineering service. The given business process must include at least four non-value-added steps.

## Learning aim A

**For Distinction standard**, learners will:

- Comprehensively map a given business process and suggest feasible and suitable improvements by making logical changes that will reduce or eliminate the waste identified in the entire business process.
- Evaluate the benefits gained from each change, for example by:
  - assessing how reordering the steps in the business process so that all operations using the same machine are carried out together reduces unnecessary movement
  - assessing how altering the types of tools or equipment being used can reduce set-up and processing time.

**For Merit standard**, learners will:

- Comprehensively map a given business process for the manufacture of an engineering product or the delivery of an engineering service. The resulting flow chart will contain no obvious omissions or oversimplifications.
- Identify at least four non-value-added steps on the business process flow chart.
- Suggest improvements by making logical changes to the business process flow chart to reduce most of the waste in the entire business process and to eliminate the four non-value-added steps identified. In each case the business process changes should be feasible in practice.
- Produce a flow chart that is logically structured, clearly laid out and easy to follow and accurately reflects the mapped business process. Annotation will be used where appropriate to provide relevant information on the business process changes.

**For Pass standard**, learners will:

- Map a given business process for the manufacture of an engineering product or the delivery of an engineering service. The resulting flow chart may contain some obvious omissions or oversimplifications, for example transporting components between work areas may be on the flow chart as a single step when it should be broken down further into loading, moving, unloading steps etc.
- Identify at least two non-value-added steps on the business process flow chart.

- Suggest improvements by making sensible changes to the business process flow chart to reduce some waste or to eliminate the two non-value-added steps identified. In each case, the business process changes should be feasible in practice, for example by reordering the steps in the process so that all operations using the same machine are carried out together, which will reduce unnecessary movement.
- Produce a flow chart that is logically structured, easy to follow and reflects the mapped business process.

### Learning aim B

The assessment activity for learning aim B must allow learners the opportunity to implement 5S in an appropriate engineering work area. The engineering work area chosen should be one that will clearly benefit from a 5S implementation.

**For Distinction standard**, learners will:

- Conduct all aspects of 5S implementation in an engineering work area in a clearly organised, methodical and systematic manner.
- Cover all aspects of the engineering work area and the 5S implementation will be comprehensive and effective.
- Evaluate the contextual benefits gained from the effective implementation of 5S in an engineering work area, for example by comparing the time and effort required to complete the 5S implementation and to train people to carry out the activities in a standardised manner against the short- and long-term rewards, such as improved productivity and morale.

**For Merit standard**, learners will:

- Demonstrate a systematic approach when carrying out a comprehensive 5S engineering work area scan using an appropriate checklist. For example, all relevant problems or omissions will be identified.
- Effectively implement the sort, straighten, shine and standardise phases of 5S (guided by the work area scan). They will show a clearly organised, methodical and systematic approach to their work, resulting in all problems or omissions identified in the work area scan being fully addressed.

**For Pass standard**, learners will:

- Carry out a 5S engineering work area scan using an appropriate checklist. They may lack a systematic approach to the engineering work area scan, for example they may miss some problems or omissions in a work area that should have been recorded.
- Implement the sort, straighten, shine and standardise phases of 5S (guided by the work area scan). They may lack a clearly organised, methodical and systematic approach to their work, which may lead to some problems or omissions identified in the engineering work area scan not being fully addressed.

### Links to other units and curriculum subjects

This unit links to, for example:

- Unit 16: Application of Quality Control and Measurement in Engineering
- Unit 22: Electrical and Electronic Circuit Construction and Testing
- Unit 28: Automated Systems.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from engineering companies who can show how business improvement techniques are used in their organisations and how they have changed working practices for the better
- access to engineering work areas that are in need of review or where problems or omissions can be simulated so learners can improve them using the techniques learnt in this unit, enabling them to see the potential 'real world' impact of their new knowledge, understanding and skills.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Eliminating problematic waste by using process mapping to identify areas for improvement.

### Managing information

- Understanding how potentially complex information can be distilled into a simple and standardised format, which is clear and easily understood at a glance.

# Unit 13: Operations and Maintenance of Mechanical Systems and Components

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will investigate mechanical systems and their components and carry out fault finding, fault rectification and routine maintenance procedures on such systems and components safely.

## Unit introduction

Have you ever thought about the consequences of the mechanical gearbox on a factory or warehouse conveyor belt system developing a fault or breaking down completely? As well as the inconvenience of having the system out of action, the resulting loss of production will affect company profits and possibly jobs.

The first step when reviewing a mechanical system is to see if the power input has been cut off, for example a motor failure. This is comparable to checking whether the fuel supply to a car engine has been lost. If the fuel is coming through, then the fault must be with one or more of the components within the engine. How do you, or a service technician, identify and rectify the fault? How do you maintain a system to help avoid faults occurring?

In this unit, you will start by investigating the function and operation of simple mechanical systems and the components within them. You will then go on to identify faults in mechanical systems and correct them by replacing components. Referring to fault finding aids such as system specifications and maintenance manuals will help you do this.

In the final part of the unit, you will carry out routine maintenance procedures and assess the importance of safety and the control of hazards and risks. Any type of maintenance must be carried out in a safe manner. It is very important that machinery is locked out so that it cannot be started up by mistake, so you will learn how to work safely when carrying out routine maintenance.

## Learning aims

In this unit you will:

**A** Investigate the function and operation of mechanical systems and the components used in them

**B** Select components used in mechanical systems during maintenance

**C** Safely carry out fault-finding and fault-rectification techniques on mechanical systems and their components

**D** Safely carry out routine maintenance procedures on mechanical systems.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate the function and operation of mechanical systems and the components used in them | **A1** Mechanical systems<br>**A2** System components<br>**A3** System faults | A portfolio, which includes a system diagram, flow chart or assembly diagram, information on a mechanical system, given maintenance procedures and evidence of where data about components can be found. This evidence could be screenshots and marked-up photocopies of pages taken from manufacturers' catalogues. |
| **B** Select components used in mechanical systems during maintenance | **B1** System data<br>**B2** Component data<br>**B3** Component selection | |
| **C** Safely carry out fault-finding and fault-rectification techniques on mechanical systems and their components | **C1** Identification of faults in a mechanical system<br>**C2** Fault rectification | A portfolio which includes the fault-finding steps and the techniques used relating to the rectification work of a mechanical system. It should include a written report relating to these techniques and work. A witness statement/ observation record along with annotated photographs would supplement the practical evidence. |
| **D** Safely carry out routine maintenance procedures on mechanical systems | **D1** Routine maintenance<br>**D2** Safety | A portfolio of the record of routine maintenance procedures followed and risks assessed, supported by witness statements/ observation records and annotated photographs. It should include a written report relating to these procedures and control measures used after assessing hazards and risks. |

# Content

## Learning aim A: Investigate the function and operation of mechanical systems and the components used in them

### A1 Mechanical systems

Function and operation of a system, including:

- power transmission – belt and chain drives, gearbox, transmission shaft
- lifting and handling – crane, hoist, jack, roller and belt conveyor, robot arm, weighing equipment
- rotary – pump, compressor, mixer, portable power tool, pillar drill, centre lathe
- fluid – pneumatic actuator, position sensor, control valve
- control – mechanical governor, servo-system.

Diagrammatic representation of the system, including:

- block/system/assembly diagram
- flow chart.

### A2 System components

Function and operation of components, including:

- bearings – plain journal, thrust, ball, roller, needle
- circular oil seal
- gasket
- shim
- hose
- lubricating devices – grease nipples and cups, capillary action, gravity-fed, pressure-fed
- fastenings – nuts and bolts, screws, self-tapping screws, studs, rivets, locking devices, key
- other components – spring, coupling, circlip, dowel, lever, pulley, belt, sprocket, chain, gear, cam, shaft, guard.

### A3 System Faults

Typical system/component fault symptoms and causes including:

- pressurisation faults such as low or high fluid levels, blocked filters, pipeline constrictions, faulty pressure relief vales, pump faults
- control system faults such as faulty sensors, faulty control valves, faulty actuators
- power train faults such as worn chains and belts, worn sprockets and pulleys, stretched chains and pulleys, twisted transmission shafts.

## Learning aim B: Select components used in mechanical systems during maintenance

### B1 System data

Sources of system information, including:

- charts, e.g. flow chart, assembly drawing, block diagram
- parts schedule/spares list
- maintenance procedure.

### B2 Component data

Sources of component data, including:

- manufacturers' catalogues
- data sheet
- repair manual
- parts list.

### B3 Component selection

Use appropriate documents and other appropriate resources to identify components to be used in given maintenance activities including:

- fault isolation flow charts
- service schedules
- maintenance procedures
- cost of replacement parts such as Original Equipment Manufacturers (OEM) and third-party suppliers
- availability of alternative components.

## Learning aim C: Safely carry out fault-finding and fault-rectification techniques on mechanical systems and their components

### C1 Identification of faults in a mechanical system

Types of fault, including:

- intermittent operation
- partial failure/out-of-specification output
- complete breakdown.

Aids to determining faults, including:

- system specification
- system diagram, component data sheets
- operations and maintenance manual
- fault codes
- previous fault/repair reports
- functional and troubleshooting charts
- final test and handover procedures
- software based records and data
- instruments – measuring equipment.

Fault-finding techniques, including:

- six point (collect evidence, analyse evidence, locate fault, determine and remove cause, rectify fault, check system)
- half split
- unit substitution
- visual examination.

### C2 Fault rectification

Equipment, including:

- taps, dies, easy-outs, drills
- torque wrench
- circlip pliers
- soft-faced mallet
- drifts
- puller
- screwdrivers, hex keys, spanners
- other assorted hand tools
- cleaning materials
- jointing compound.

Removal and replacement of faulty components, including:

- components – remove, test, repair, source replacement, re-fit
- procedures – remove mechanical fixings, unclip electrical connectors, dismantle, align
- post-rectification tests and checks
- record actions – job card, checklist.

## Learning aim D: Safely carry out routine maintenance procedures on mechanical systems

### D1 Routine maintenance

Inspection checks and tests, including:

- visual examination – leak detection, wear, chafing, fouling, corrosion
- overheating
- security of attachment/fixings
- noise
- lubricant levels
- pressures.

Routine maintenance procedures, including:

- adjustments
- replacing components
- replacing/changing consumables
- testing against specification.

Record actions on formal documentation, including:

- job card
- checklist
- routine maintenance report
- sign-off documentation.

**D2 Safety**

Workplace hazards and risks, including:

- pressurised systems
- unfenced machinery
- incorrect isolation of prime movers
- non-lockout of moving parts
- toxic substances
- badly maintained tools and equipment.

Safety awareness while carrying out routine maintenance on mechanical systems, including:

- hazards and risks
- people at risk
- control measures and their effectiveness
- risk assessment documentation.

Keeping safe in a mechanical maintenance environment, including:

- personal protective equipment (PPE)
- safe working practices – permit to work, danger tags, warning notices, safety barriers, isolation, treatment for eye injury (fluid and particle penetration) and other procedures in case of injury, accident reporting
- approved working procedures.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Investigate the function and operation of mechanical systems and the components used in them</td><td rowspan="4">AB.D1 Evaluate the function and operation of a mechanical system, the impact that component faults have on the reliability of a mechanical system and the selection of components to facilitate mechanical system maintenance.</td></tr>
<tr><td>A.P1 Describe the function and operation of a mechanical system.<br>A.P2 Describe the function and operation of different components used in a mechanical system.</td><td>A.M1 Explain the function and operation of a mechanical system and its components and the relationship between a mechanical system malfunction and component faults.</td></tr>
<tr><td colspan="2">Learning aim B: Select components used in mechanical systems during maintenance</td></tr>
<tr><td>B.P3 Select components to be used in mechanical system maintenance.<br>B.P4 Use mechanical system and component data sources.</td><td>B.M2 Justify the selection of components used in mechanical system maintenance.</td></tr>
<tr><td colspan="2">Learning aim C: Safely carry out fault-finding and fault-rectification techniques on mechanical systems and their components</td><td rowspan="2">C.D2 Justify the use of specific fault-finding aids and techniques and specific fault rectification equipment when identifying mechanical system faults and replacing faulty components.</td></tr>
<tr><td>C.P5 Identify mechanical system faults using fault-finding aids and techniques.<br>C.P6 Use fault rectification equipment to replace faulty components in a mechanical system.</td><td>C.M3 Explain the use of fault-finding aids and techniques and fault rectification equipment when identifying mechanical system faults and replacing faulty components.</td></tr>
<tr><td colspan="2">Learning aim D: Safely carry out routine maintenance procedures on mechanical systems</td><td rowspan="2">D.D3 Evaluate specific hazards and risks and the effectiveness of specific control measures when safely carrying out routine maintenance procedures on a mechanical system.</td></tr>
<tr><td>D.P7 Identify the hazards and risks before carrying out routine maintenance procedures on a mechanical system.<br>D.P8 Demonstrate safety awareness and how to keep safe when carrying out routine maintenance procedures on a mechanical system.</td><td>D.M4 Explain the hazards and risks and which control measures should be used when safely carrying out routine maintenance procedures on a mechanical system.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, B.P4, A.M1, B.M2, AB.D1)

Learning aim: C (C.P5, C.P6, C.M3, C.D2)

Learning aim: D (D.P7, D.P8, D.M4, D.D3)



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# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- all required safety equipment
- a workshop environment suitable for carrying out fault finding, rectification and routine maintenance procedures
- mechanical systems that have faults which are straightforward to identify and can be rectified by replacement or substitution of components
- fault finding aids and rectification equipment and tools
- relevant manufacturers' service manuals, data sheets, parts lists, drawings and diagrams, etc.

## Essential information for assessment decisions

## Learning aims A and B

To enable learners to achieve the requirements of these two learning aims, the mechanical system should be one from those listed in A1 in the *Content* and must have at least four components that could be replaced during a maintenance activity.

A good example would be a power transmission where some of the sub-assemblies such as the gearbox are likely to have several component parts, for example, a spur gear, plain journal bearing, seal, woodruff key etc.

**For Distinction standard**, learners will:

- Evaluate the component selection and reliability of a mechanical system. The evidence will include consideration of the economic issues relating to the maintenance of a system – for example, the cost of labour, consumables, replacement components and system downtime. The evaluation will be supported by a block diagram or flow chart and references made to inputs and outputs allowing a non-engineer to clearly see the evaluation outcomes.
- Provide evidence to clearly show the relationship between faults and system malfunction (reliability) and why certain components have been selected and others not.

**For Merit standard**, learners will:

- Explain the effects of component faults on the function and operation of a mechanical system. They will need to consider both a full and partial system malfunction and the consequences if a system is not reliable. The explanation should be supported with a block diagram or flow chart and references made to inputs and outputs. The explanation should allow a non-engineer to see how the faults relate to system malfunction.
- Justify the selection of at least four replacement components; for example, the selection of an Original Equipment Manufacturer (OEM) component over one from a much cheaper third-party supplier. As part of the justification learner will need to consider cost of the parts, suitability and reliability.

**For Pass standard**, learners will:

- Describe the function and operation of a mechanical system. The description must be supported with a block diagram or flow chart and will include details of the system inputs and outputs.
- The description should allow a non-engineer to know how the system works and what it is for.
- Describe the function and operation of at least four different components found within the system. These should be of different type, for example not just four pulleys or gears of varying sizes.
- The description should allow a non-engineer to see how the components work and what they are for.
- Use appropriate documents as detailed in the unit content to identify components to be used in a mechanical system maintenance activity. Learners will select appropriate components that could be replaced. Having selected the relevant components, learners should access published data so that they can specify part numbers on a parts schedule or spares list. The published data should include all four sources of component data forms as in B2 in the unit *Content*.

### Learning aim C

To enable learners to achieve the requirements of this learning aim, the mechanical system should be one from those listed in A1 in the *Content*. It should have a range of faults that will require the use of at least two fault finding techniques and four aids from those listed in C1 in the *Content*. A good example would be an electrical crane or hoist where visual examination could be used to establish potential damaged components and the half split method could be used to identify electrical issues and faults. Most of the aids to determine faults could be used here. The fault-finding activity must lead to the replacement of at least three faulty components. The use of fault rectification equipment will depend on the type of rectification and replacements required but learners must use at least four types of equipment from C2 in the *Content*.

**For Distinction standard**, learners will:

- Justify the use of at least two of the fault-finding techniques listed in the unit content and at least two aids listed in the unit content when identifying faults on mechanical systems. The justification will be sufficiently detailed and will include why a particular technique or aid would be used instead of alternative approaches. Learners must also justify the use of at least one piece of specific rectification equipment and will detail why alternative equipment was rejected.

**For Merit standard**, learners will:

- Explain how at least two different fault-finding aids and techniques are used when identifying mechanical system faults.
- Explain how fault rectification equipment is used when replacing faulty components.



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**For Pass standard**, learners will:

- Apply at least two of the fault-finding techniques listed in the unit content and use at least four aids listed in the unit content when identifying faults on one or more mechanical systems. Learners may sometimes require support from the assessor to ensure that the type of fault is investigated properly.
- Identify and replace at least three faulty components after fault finding, and after rectification run post-rectification tests to ensure that the system is operating as expected. During this activity at least four pieces of fault rectification equipment are expected to be used.
- Provide completed job cards/checklists that accurately reflect a true record of the actions taken during the component replacement activity and checking for serviceability.

### Learning aim D

To enable learners to achieve the requirements of this learning aim, the mechanical system should be one from those listed in A1 in the *Content*. The routine maintenance activity must include the requirement for at least three inspection checks and tests and three routine maintenance procedures from those listed
in Topic D1 in the *Content*.

**For Distinction standard**, learners will:

- Evaluate the hazards, and risks associated with a given mechanical maintenance activity. They will also give balanced reasons for the selection of particular control measures, evaluating their effectiveness in ensuring the maintenance activity is carried out safely.

**For Merit standard**, learners will:

- Explain the hazards and risks associated with a given routine maintenance task on a mechanical system. Learners must also explain appropriate measures that could be used to control these hazards and risks.

**For Pass standard**, learners will:

- Identify the hazards and risks within a workplace where routine maintenance is to be carried out on a mechanical system.
- Carry out routine maintenance on a mechanical system utilising at least three inspection checks and tests and three routine maintenance procedures and record actions using at least one type of formal documentation.
- Show a safety awareness and due regard to hazards and risk and people at risk.
- Demonstrate how to keep safe by compliance with the use of PPE, safe working practices and approved working practices throughout all of the routine maintenance activities.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 15: Engineering Marking Out
- Unit 16: Application of Quality Control and Measurement in Engineering.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, to share insights into industrial operations and maintenance of mechanical systems, as well as fault finding and fault rectification techniques and routine maintenance procedures
- documentation, such as block/system or assembly diagrams for mechanical systems, along with manufacturers' catalogues and repair manuals
- work experience that will allow learners to become familiar with industrial mechanical systems and the typical environments in which they are used. The nature of the knowledge and skills being developed in this unit mean that it is particularly suited to incorporating a period of work experience. Learners could, for example, shadow a maintenance engineer when carrying out fault finding, rectification or routine maintenance procedures
- support from a maintenance engineer or supervisor, to co-teach practical lessons and to provide feedback and developmental advice to learners as their skills develop. This would help to ensure that skills are taught effectively and mirror those in current use in industry.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate fault finding and routine maintenance techniques to rectify faults and maintain mechanical systems.

### Managing information

- Collecting, recording and interpreting system and component data.

### Self-management and development

- Development of practical skills relating to fault finding and maintaining mechanical systems will be self-managed by learners.



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# Unit 14: Fabrication Techniques

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will use a range of materials, tools and techniques to safely manufacture component parts of fabricated structures and to assemble and check fabricated structures.

## Unit introduction

Have you ever wondered how the parts of a computer fit so neatly and precisely into a computer case? It's because of fabrication techniques. They enable a sheet of thin metal to be cut and formed with accuracy and precision to allow all of the computer parts to be assembled securely inside.

This unit will help you to understand fabrication techniques that are used in industry to prepare, cut, form and assemble materials and components. This is a predominantly practical unit and you will have the opportunity to investigate and work with different material forms as well as fixtures and fittings that are used when manufacturing fabricated structures.

Health and safety is a vital consideration in any fabrication work area and you will also learn about general housekeeping as well as how to handle and use tools, equipment and techniques safely.

You will refer to drawings and work instructions in order to measure and mark out materials ready for fabrication and will use cutting and forming techniques to prepare component parts that are required for assembly. You will use a variety of tools and techniques, including joining processes, to assemble fabricated structures and will also use the drawings and work instructions to check that you are meeting all the necessary compliance and accuracy requirements when carrying out practical activities.

## Learning aims

In this unit you will:

**A** Safely manufacture component parts of fabricated structures

**B** Safely assemble and check fabricated structures.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Safely manufacture component parts of fabricated structures | **A1** Preparing for a fabrication activity<br>**A2** Carrying out a fabrication activity<br>**A3** Measuring and marking out<br>**A4** Material forms<br>**A5** Materials<br>**A6** Cutting<br>**A7** Forming<br>**A8** Closing down a fabrication work area | A practical activity involving the preparation for manufacture and subsequent safe manufacture of two component parts of a fabricated structure.<br>The assessment evidence will include the finished component parts and images of them, a logbook containing written notes and sketches, annotated photographs of the preparation process and work-in-progress and/or videos with learner narration and learner observation records/ witness statements. |
| **B** Safely assemble and check fabricated structures | **B1** Joining processes<br>**B2** Assembly<br>**B3** Quality and accuracy standards | A practical activity involving the preparation for assembly and subsequent safe assembly of two fabricated structures.<br>The assessment evidence will include the completed fabricated structures and images of them, a logbook containing written notes and sketches, annotated photographs of the preparation process and work-in-progress and/or videos with learner narration, quality control records and learner observation records/ witness statements. |

## Content

### Learning aim A: Safely manufacture component parts of fabricated structures

#### A1 Preparing for a fabrication activity

In a fabrication work area:

- identifying hazards and carrying out risk assessments
- selecting correct and appropriate personal protective equipment (PPE)
- obtaining and understanding drawings/work instructions, e.g. third angle orthographic, isometric, assembly drawings, parts drawings, parts lists, job cards
- obtaining suitable tools and materials and carrying out checks to ensure that they are safe and in a usable condition.

#### A2 Carrying out a fabrication activity

In a fabrication work area:

- correct procedures to carry out given tasks
- working safely at all times
- recording actions, including processes, problems and results.

#### A3 Measuring and marking out

Safe use of tools and equipment for measuring and marking out:

- measuring tools, e.g. rule, tape rule, protractor, height gauge
- marking out tools, e.g. scriber, centre punch, chalk line, square, trammel, dividers, templates, surface plate, chalk, engineer’s blue, laser measuring and marking equipment
- features, e.g. datum lines and centre lines, square and rectangular profiles, circles, curved profiles, cutting detail, hole centring, circular outlining, linear outlining.

#### A4 Material forms

Material forms of common engineering materials and standard fixtures and fittings:

- sheet, plate and material sections up to and including 3 mm thickness, e.g. hot-rolled black and cold-rolled
- standard bar and section lengths, standard profiles, cutting detail for flat covers and plates, frames, pipe and tube sections, columns, beams, struts
- fixtures and fittings used in fabrication, e.g. seals, gaskets, trims, panels, screens, fish plates, gussets, spars and brackets, structural support pads, bed plates.

#### A5 Materials

Types of material used in fabrication:

- metallic – ferrous and non-ferrous, e.g. low carbon steel, tinned steel, galvanised steel, aluminium, stainless steel, brass, copper
- non-metallic – polymers and rubbers, e.g. mouldings, sheets and extrusions.

### A6 Cutting

Safe use of cutting tools and techniques:

- hand tools, e.g. tin snips, hacksaw, files
- hand power tools, e.g. drill, nibbler
- machine tools, e.g. bench shears, band saw, guillotine, pillar drill, punch, cropper
- machine cutting operations – straight cuts, external contoured cuts, round holes
- filing
- drilling.

### A7 Forming

Safe use of forming tools and techniques:

- tools and equipment, e.g. hammers, mallets, stakes, formers, hand bending, sheet metal folder, powered bending machines, hand rolling, powered rolling machines
- safety checks on tools and equipment, e.g. hammer shafts are secure, striking faces on stakes and formers are free from burrs and defects, machine guards and devices are operational
- operations – bends, folds, curved panels, cylindrical section, ducting/trunking.

### A8 Closing down a fabrication work area

- Completing all tasks and relevant documentation.
- Leaving the work area clean, tidy and safe.
- Returning drawings/work instructions and tools on completion.
- Disposing of unusable tools, equipment and waste materials.

## Learning aim B: Safely assemble and check fabricated structures

### B1 Joining processes

Types of permanent and non-permanent joining:

- thermal, e.g. tack welding, brazing, soldering, resistance spot welding
- mechanical fasteners, e.g. hollow rivets, solid rivets, self-piercing rivets, threaded inserts, structural fasteners, bolts, screws
- adhesives, e.g. structural adhesives, epoxides, acrylics, cyanoacrylates.

### B2 Assembly

Types of assembly:

- straightforward assembly characterised by linear edges, perpendicular changes of section and regular joins, e.g. regular shaped frames/hoods/guards/panels, regular sectioned ducting/trunking, square, rectangular and box sections, cylindrical sections
- more complex assembly characterised by non-linear edges, changes of section which are not necessarily perpendicular and irregular joins, e.g. reduction pieces, irregular shaped frames/hoods/guards/panels, sectioned ducting/trunking incorporating changes in section/cross sectional area, irregular shaped box sections, oval and tapered cylindrical sections.

Types of components in used in assembly:

- straightforward components, e.g. regular sheet metal covers, prefabricated square and rectangular components, prefabricated cylindrical and conical components, brackets, light rolled angle or tee section
- more complex components, e.g. irregular sheet metal covers, prefabricated non-square/rectangular components, prefabricated non-circular cylindrical and conical profiles, flanges, pipes, light rolled channel or I form section.

**B3 Quality and accuracy standards**

Visual and specific checks for compliance and accuracy using suitable tools and equipment to ensure:

- components are aligned in accordance with the given drawings/work instructions
- overall dimensions are within linear tolerances
- overall dimensions are within geometrical tolerances, e.g. square, straight, free from twists, pitches of erection holes meet requirements
- joints are secure and firm
- fabricated structures are clean, free from burrs and sharp edges and conform to any aesthetic requirements.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Safely manufacture component parts of fabricated structures** | | |
| **A.P1** Manage a work area safely when manufacturing two component parts of a fabricated structure.<br>**A.P2** Measure and mark out material forms for two component parts of a fabricated structure.<br>**A.P3** Demonstrate the safe use of cutting and forming tools and techniques when manufacturing two component parts of a fabricated structure. | **A.M1** Safely and accurately manufacture two component parts of a fabricated structure, showing a good level of skill. | **A.D1** Safely and accurately manufacture two component parts of a fabricated structure, showing a high level of adaptability and skill. |
| **Learning aim B: Safely assemble and check fabricated structures** | | |
| **B.P4** Select and use suitable permanent and non-permanent joining methods to safely assemble two fabricated structures.<br>**B.P5** Use straightforward and more complex types of component to safely assemble two fabricated structures.<br>**B.P6** Carry out quality control checks for compliance and accuracy during and after the assembly of two fabricated structures. | **B.M2** Safely and accurately assemble two fabricated structures, showing a good level of skill. | **B.D2** Safely and accurately assemble two fabricated structures, showing a high level of adaptability and skill. |



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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.D1)

Learning aim: B (B.P4, B.P5, B.P6, B.M2, B.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- an appropriately equipped fabrication work area
- measuring, marking out, cutting and forming tools and equipment as required by the learning aims and the *Content* section
- materials, fixtures and fittings as required by the learning aims and the *Content* section
- tools and equipment that facilitate the use of permanent and non-permanent joining techniques as required by the learning aims and the *Content* section
- straightforward and more complex types of component as required by the learning aims and the *Content* section
- a range of drawings and work instructions that include quality requirements and provide the opportunity to manufacture component parts of fabricated structures and assemble and check fabricated structures.

## Essential information for assessment decisions

## Learning aim A

The two component parts of a fabricated structure between them must:

- be manufactured using at least two different material forms, for example sheet and tube sections, as defined in the *Content* section
- be manufactured using at least two different materials, for example low carbon steel and aluminium, as defined in the *Content* section
- require the use of at least five different tools to measure and mark them out, for example height gauge, scriber, centre punch, square and surface plate
- require the use of at least five different tools to cut them and at least one of the tools must be a power or machine tool, for example tin snips, hacksaw, bench shears, nibbler and guillotine, as defined in the *Content* section
- require the use of at least five different tools to form them and at least one of the tools must be powered, for example mallet, stake, formers, sheet metal folder and rolling machine, as defined in the *Content* section
- have accuracy, aesthetic and functional quality requirements.

**For Distinction standard**, learners will:

- Be safe and systematic at all times when measuring, marking out, cutting and forming two component parts of a fabricated structure.
- Recognise any adjustments that may be necessary and adapt their approach during the manufacture of two component parts of a fabricated structure to ensure that they are working effectively.
- Generate two component parts of a fabricated structure that are accurate, function as intended and have no aesthetic issues.

**For Merit standard**, learners will:

- Be organised and observe safe working practices at all times.
- Demonstrate confidence in their working when measuring, marking out, cutting and forming two component parts of a fabricated structure, although some of their decisions may result in unnecessary extra activities and may slow their progress at times.

- Generate two component parts of a fabricated structure that are mostly accurate and function as intended, although one component part may not fully meet the quality requirements.

**For Pass standard**, learners will:

- Demonstrate that they can safely prepare and manage a fabrication work area by:
  - selecting and using the correct PPE
  - obtaining the correct drawings, instructions and materials
  - selecting suitable tools and equipment for measuring, marking out, cutting and forming and by performing checks to make sure the tools and equipment are fit for purpose
  - following required procedures to control any risks
  - leaving it in a clean and tidy condition and by storing drawings, instructions, tools and equipment in the correct place upon completion of manufacturing activities.
- Appropriately carry out a range of both measuring and marking out activities on at least two different material forms and two different materials with some guidance so that two component parts of a fabricated structure can be manufactured.
- Safely use a range of cutting and forming tools and techniques to manufacture two component parts of a fabricated structure with some guidance. The quality requirements may not be fully met for both of the component parts, for example there may be aesthetic or accuracy issues, but both will be functional.

## Learning aim B

The two fabricated structures between them must:

- include the requirement for straightforward assembly characterised by linear edges, perpendicular changes of section and regular joins, as defined in the *Content* section
- include the requirement for more complex assembly characterised by non-linear edges, changes of section which are not necessarily perpendicular and irregular joins, as defined in the *Content* section
- be manufactured using at least three different thermal joining methods, for example brazing, soldering and resistance spot welding, as defined in the *Content* section
- be manufactured using at least four different types of mechanical fasteners, for example solid rivets, threaded inserts, structural fasteners and bolts, as defined in the *Content* section
- be manufactured using at least one type of adhesive, for example cyanoacrylates, as defined in the *Content* section
- include the requirement to assemble at least two types of straightforward component, for example a regular sheet metal cover and a bracket, as defined in the *Content* section
- include the requirement to assemble at least two types of more complex component, for example an irregular sheet metal cover and a flange, as defined in the *Content* section
- have quality requirements relating to linear and geometric tolerances.

**For Distinction standard**, learners will:

- Be safe and systematic at all times when using a combination of different types of mechanical fasteners, thermal joining methods, an adhesive and a range of straightforward and more complex types of component to assemble two fabricated structures. They will recognise any adjustments that may be necessary and adapt their approach during the assembly of two fabricated structures to ensure that they are working effectively.
- Carry out all relevant and necessary quality control checks in an accurate manner both during and after the assembly of two fabricated structures. They will generate detailed and correct quality records to show that they carried out all relevant and necessary quality control checks and that they adapted their approach based on the information provided to ensure the compliance and accuracy of both fabricated structures.
- Assemble two fabricated structures that are accurate, function as intended and have no aesthetic issues.

**For Merit standard**, learners will:

- Be organised and observe safe working practices at all times.
- Demonstrate confidence in their working when using a combination of different types of mechanical fasteners, thermal joining methods, an adhesive and a range of straightforward and more complex types of component to assemble two fabricated structures, although some of their decisions may result in unnecessary extra activities and may slow their progress at times.
- Carry out quality control checks in an accurate manner both during and after the assembly of two fabricated structures. They will generate suitable quality control records to evidence the visual and specific quality checks carried out. They may not always carry out the quality control checks at appropriate times during the assembly of two fabricated structures, leading to minor quality issues such as burring.
- Assemble two fabricated structures that are mostly accurate and function as intended, although one fabricated structure may not fully meet the quality requirements.

**For Pass standard**, learners will:

- Appropriately select and safely use a combination of different types of mechanical fasteners, thermal joining methods and an adhesive, with some guidance, to safely assemble two fabricated structures.
- Safely use a range of straightforward and more complex types of component, with some guidance, to safely assemble two fabricated structures.
- Carry out quality control checks during and after the assembly of two fabricated structures. They will generate quality control records to evidence the quality checks carried out. They may not carry out relevant and accurate quality checks at appropriate times during the assembly of two fabricated structures and may fail to recognise the significance of the information provided, meaning that inaccuracies occur.
- The quality requirements may not be fully met for both of the fabricated structures, for example there may be aesthetic or accuracy issues, but both will be functional.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 15: Engineering Marking Out
- Unit 16: Application of Quality Control and Measurement in Engineering.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, such as technicians, to talk to learners about safe working practices, procedures for setting up work areas and how to use fabrication techniques effectively
- documentation, such as the provision of a range of suitable drawings and associated work instructions
- work experience in the fabrication sector, by offering the opportunity to carry out a greater range of practical activities
- industrial visits to fabrication work areas, in order to gain a greater understanding of how techniques are used and how processes are carried out when manufacturing for a customer.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate tools, techniques, processes and components so that practical fabrication activities can be completed.

### Managing information

- Gaining skills in the interpretation of drawings and work instructions so that practical fabrication activities can be completed and collecting, recording and interpreting quality data.

### Self-management and development

- Prioritising activities and gaining an understanding of the relationship between different tasks in order to organise time and resources when working in a fabrication work area.

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# Unit 15: Engineering Marking Out

Level: **2**
Unit type: **Internal**
Guided learning hours: **30**

## Unit in brief

Learners will consider and use marking out methods and equipment to safely carry out the marking out of engineering workpieces.

## Unit introduction

Have you ever wondered how engineered components used in development or prototype work are made with such precision and minimum waste? This can be because of precise marking-out procedures. The manufacture of a workpiece normally starts from raw materials that must be formed and shaped into the component parts.

In this unit, you will gain the knowledge and skills needed to measure and mark out workpieces in preparation for further engineering operations. This first step in the manufacture of an engineered product is critical to all the processes that follow.

This unit will give you an opportunity to consider marking-out methods, equipment and applications, how to care for and use measuring and marking-out equipment and why calibration is important. You will also carry out a range of marking-out activities, including the selection of appropriate measuring, marking-out and work-holding equipment. You will work with and mark-out square or rectangular, circular or cylindrical, and irregular-shaped workpieces.

An important aspect of this unit is the consideration of safe working practices in the engineering workplace when carrying out the marking out of workpieces.

## Learning aims

In this unit you will:

**A** Know about marking-out methods and equipment for different applications

**B** Be able to mark out engineering workpieces to specification using safe working practices.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Know about marking-out methods and equipment for different applications | **A1** Measuring and marking-out methods and equipment<br>**A2** Marking-out applications | A report based on a practical activity involving the use of tooling, measuring equipment and work-holding devices to mark out three different applications.<br>The assessment evidence will include the finished marked-out workpieces and a report with annotated images/diagrams/photographs and/or videos with learner narration, learner observation records/witness statements detailing what was done and why, and suggested improvements. |
| **B** Be able to mark out engineering workpieces to specification using safe working practices | **B1** Marking out<br>**B2** Safe working practices<br>**B3** Quality and accuracy standards | |



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## Content

### Learning aim A: Know about marking-out methods and equipment for different applications

#### A1 Measuring and marking-out methods and equipment

Know about:

- measuring and marking-out methods: datum faces, reference points to be used
- equipment required:
  - tooling, e.g. engineer's rule, scriber, centre punch, dividers, odd-leg calipers, engineer's square, scribing block
  - measuring equipment, e.g. vernier protractor, vernier height gauge, dial test indicators, slip gauges
  - work-holding devices, e.g. surface tables/plates, angle plates, vee-blocks, clamps
  - marking-out mediums, e.g. marking blue, lacquer, whitewash.
- the importance of care and calibration:
  - calibration e.g. tracing measurement back to known standard, checking accuracy of equipment, resetting accuracy of equipment
  - care e.g. protect from corrosion and damage, return to storage, only use for designed purpose
  - range of equipment e.g. tooling, measuring equipment, marking-out equipment
  - importance e.g. inaccurate readings, to ensure reliability and consistency, maintain warranty of equipment, maintain equipment safety, to protect equipment, to keep equipment clean and ensure traceability back to standards.

#### A2 Marking-out applications

Identify a range of measuring and marking-out methods and equipment when marking out given applications:

- square/rectangular: e.g. bar stock, sheet material
- circular/cylindrical: e.g. bar stock, tubes, turned components, flat discs
- irregular shapes: e.g. castings, forgings, odd-shaped components.

### Learning aim B: Be able to mark out engineering workpieces to specification using safe working practices

#### B1 Marking out

Demonstrate how to prepare for a range of marking-out activities:

- work plan: reading engineering drawings/job instructions, planning the sequence of marking-out operations, identifying materials and equipment required.

Carry out marking-out activities:

- preparation of workpiece: checking for visual defects, removing burrs, component cleaning
- setting and positioning workpieces using equipment: e.g. squares, dial test indicators, slip gauges, packing pieces, jacks
- marking out to a planned sequence of operations: datum and centre lines; features, e.g. square/rectangular profiles, angle/angular profiles, circles, linear hole positions, pattern developments (cones and pyramids).

### B2 Safe working practices

Use a range of safe working practices when carrying out marking-out activities:

- personal protection and hygiene procedures: overalls, eye protection, safety shoes/boots, barrier creams
- safe working environment: safe use of tools, cleaning of equipment, disposal of waste, storage of marking and measuring equipment.

### B3 Quality and accuracy standards

Visual and specific checks for compliance and accuracy to ensure that marked-out features and dimensions are:

- easy to see, understandable and free from false marking out lines
- a guide for material removal processes
- indicating if sufficient machining allowance has been left
- a form of reference
- within linear tolerances
- within geometrical tolerances.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Know about marking-out methods and equipment for different applications** | | **A.D1** Evaluate the effectiveness of using different measuring and marking-out methods and equipment for different applications and the impact of not taking care of and calibrating the equipment. |
| **A.P1** Describe the measuring and marking-out methods and equipment that are used for different applications.<br>**A.P2** Describe what calibration is and how to take care of measuring and marking-out equipment. | **A.M1** Explain how measuring and marking-out methods and equipment are used for different applications and the reasons why the equipment must be taken care of and calibrated. | |
| **Learning aim B: Be able to mark out engineering workpieces to specification using safe working practices** | | **B.D2** Safely and accurately measure and mark out different workpieces, showing a high level of adaptability and skill. |
| **B.P3** Select suitable measuring and marking-out methods and equipment for different applications.<br>**A.P4** Safely prepare, set, position, measure and mark out different workpieces using a given work plan. | **B.M2** Safely measure and mark out different workpieces, showing a good level of skill. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a workshop environment and the range of tools and equipment required to mark out and measure engineering workpieces as required by the learning aims and the content section
- a range of workpiece materials, applications and drawings to gain a range of experience in line with the coverage expected in the content section
- a suitable range of health and safety equipment for personal protection.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Provide a written evaluation of the effectiveness of using measuring and marking-out methods and equipment for three different marking out applications which should include a square or rectangular, circular or cylindrical and an irregular shape. This should say how a datum face and a reference point is important in each case. For each application, the use of the equipment evaluated should include at least one different piece of tooling, measuring equipment, work holding device and one marking-out medium. Furthermore, the written evaluation should show the impact of not calibrating and taking care of measuring and marking-out equipment. The evaluation should relate to the three different applications indicating what will be the potential disadvantages if calibrating and taking care of measuring and marking-out equipment is not carried out.

**For Merit standard**, learners will:

- Provide a written explanation of the use of measuring and marking-out methods and equipment for three different marking out applications which should include a square or rectangular, circular or cylindrical and an irregular shape. This should say how a datum face is used and how a reference point is used in each case. For each application, the use of the equipment explained should include at least one different piece of tooling, measuring equipment, work holding device and one marking-out medium. Furthermore, the written explanation should show the reasons why calibration is needed and why taking care of measuring and marking-out equipment is needed. The reasons explained should relate to the three different applications.

**For Pass standard**, learners will:

- Provide a written description of the measuring and marking-out methods and equipment for three different marking out applications which should include a square or rectangular, circular or cylindrical and an irregular shape. This should say what a datum face is and what a reference point is. For each application the equipment described should include at least one different piece of tooling, measuring equipment, work holding device and one marking-out medium.

- Provide a written description to show what calibration is and how to take care of measuring and marking-out equipment. This should be a simple description such as calibration is a comparison between a known standard and the actual measurement obtained when using the equipment, it gives an opportunity to maintain accuracy. The description will also include a range of statements stating how equipment should be cared for such as avoiding damage. Statements will be simple and to the point but will show a non-engineer what calibration is and how to care for the equipment.

### Learning aim B

Learners must measure and mark out using a given work plan and the engineering drawings/job instructions must contain quality and accuracy standards that allow them to consider which methods and equipment will be most suitable. The given information should include details about what needs to be marked out, an opportunity to prepare the workpieces, such as removing burrs, and to have a requirement to set and position the workpiece before measuring and marking out can take place. By using the different applications, the marking out operations will need to include both datum and centre lines; typical examples here would be circles and linear hole positions.

The different applications for the assessment activities must include one from each of those listed in the *Content*:

- square/rectangular
- circular/cylindrical
- irregular shape.

Each workpiece must allow learners the opportunity to measure and mark out using a range of equipment and must include at least one piece from those listed in the content as tooling, such as a centre punch to dot punch hole positions; at least one from those listed as measuring equipment, such as a vernier protractor to measure an angular hole position on a pitch circle diameter; at least one from those listed as work holding devices, such as a surface table when marking out flat linear requirements; and at least one from those listed as marking-out mediums such as marking blue when marking out flat linear requirements.

**For Distinction standard**, learners will:

- Select the most suitable measuring and marking-out methods and equipment for the three different applications. They will use a given work plan to prepare and set the position of the workpieces to measure and mark out a range of features across the three applications in a manner requiring no support. The skills used will show good accuracy of outcomes and with no errors and all activity will be carried out in a safe manner. This skill level will be shown in an observation record/witness statement and will show that practices were adapted, and it was sufficient to produce accurate outcomes and was carried out safely.

**For Merit standard**, learners will:

- Select the most suitable measuring and marking-out methods and equipment for the three different applications. They will use a given work plan to prepare and set the position of the workpieces to measure and mark out a range of features across the three applications in a manner requiring little but some support to adapt practices. The skills used will show some accuracy of outcomes; errors may be present but will be minimal and all activity will be carried out in a safe manner. This skill level will be shown in an observation record/witness statement and will show that it was sufficient to produce reasonably accurate outcomes and was carried out safely.

**For Pass standard**, learners will:

- Select the most suitable measuring and marking-out methods and equipment for the three different applications. They may not be the most effective or efficient methods and equipment available to them, for example they might choose to use an oversize surface plate rather than one of a more suitable size which may cause handling problems and they might choose to use oversize vee blocks when smaller ones would be more suitable. Whatever the case the equipment should enable the marking out to take place.
- Use a given work plan to prepare and set the position of the workpieces to measure and mark out a range of features across the three applications. The skills used will not necessarily be developed fully and errors may exist which means outcomes will not be fully accurate although all activity will be carried out in a safe manner. Help may be needed to adapt practices when carrying out the practical work. An observation record/witness statement will state that the activity was carried out safely.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 14: Fabrication Techniques
- Unit 16: Application of Quality Control and Measurement in Engineering.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, to share insights into industrial marking out and measuring activities, the continued importance of related activities to a range of engineering sectors and the importance of safety in the workshop environment
- documentation, such as a range of suitable engineering drawings and associated workpieces
- work experience, which will allow learners to become familiar with industrial marking-out activities and the typical industrial environments in which they are used
- an engineering fitter or supervisor, to support practical lessons and to provide feedback and developmental advice to learners as their skills develop. This would help to ensure that the marking-out and measurement activities are taught effectively and mirror those in current use in industry.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

**Problem solving**

- Selecting the most appropriate methods, tooling, measuring equipment and work-holding devices to carry out marking-out activities.

**Managing information**

- Collecting, recording and interpreting quality data from drawings and plans.

**Self-management and development**

- Development of practical skills relating to marking out will be self-managed by learners.
- Safely and effectively self-managing the preparation and carrying out of marking-out activities.

# Unit 16: Application of Quality Control and Measurement in Engineering

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will consider aspects of quality, tolerances and types of fit and how measuring and comparator equipment are used to carry out measurement and inspection of engineered components against specifications on engineering drawings.

## Unit introduction

Have you ever wondered why so many complex engineering products are so reliable and work so well? Think about a modern car – it contains thousands of engineered components that have to be manufactured to fit lots of other parts and assemblies. If they didn't fit together properly, the reliability of the car would be compromised and it could result in safety issues and hugely expensive product recalls.

Engineering companies operate quality assurance programmes to ensure that all parts of their organisation work towards supplying quality products. Quality control is an essential part of these programmes. This involves measurement or inspection at the key stages of manufacture for dimensional and geometric accuracy and for characteristics such as surface texture and roughness. Automated equipment is sometimes used but manual measurement or inspection is still essential for many products and engineers use a large range of measuring and comparator equipment to measure or inspect the many features that make up an engineered component or assembly.

You will gain knowledge of quality and quality control in engineering. You will consider what quality is and when, how and what quality control procedures need to be carried out for specific engineered components. You will also learn about quality documentation, standards and calibration, and will be introduced to the concepts of tolerance and types of fit. The unit also aims to provide you with the knowledge and skills needed to measure or inspect engineered components, using appropriate techniques and equipment, in order to be able to measure, compare and make judgements on the accuracy of dimensional and geometric features and surface texture/roughness.

## Learning aims

In this unit you will:

**A** Know about quality and quality control in engineering

**B** Know about dimensional tolerances and types of fit for engineered components

**C** Use quality control equipment to monitor the quality of engineered components.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Know about quality and quality control in engineering | **A1** Quality<br>**A2** Quality control | A presentation/set of slides with images and text that uses engineering examples to detail the use of quality in engineering and the essential parameters of quality control and considers the types and impact of costs associated with quality. |
| **B** Know about dimensional tolerances and types of fit for engineered components | **B1** Tolerances and components | An information leaflet with images and text that shows information on tolerances and types of fit used when assembling simple components. |
| **C** Use quality control equipment to monitor the quality of engineered components | **C1** Features to be measured or inspected<br>**C2** Engineered components and engineering drawings<br>**C3** Using measurement equipment<br>**C4** Using comparator equipment<br>**C5** Engineered components | A portfolio based on a practical activity involving the use of measuring and comparator equipment to measure or inspect features of a given engineered component against engineering drawings.<br>The assessment evidence will include the engineering drawings annotated to show measurements taken against the features on the components. Alternatively, a quality control table that shows measurement or inspection outputs against the features specified on the engineering drawings.<br>The portfolio will include a written section about types of measuring and comparator equipment, annotated images/diagrams/ photographs and/or videos with learner narration, learner observation records/ witness statements detailing what was done and why and details of the quality of each component with reference to their engineering drawings and fitness for purpose. |

# Content

## Learning aim A: Know about quality and quality control in engineering

### A1 Quality

Meanings for the term 'quality' in engineering, including:

- fitness for purpose
- safe to use
- meeting customer requirements
- use of global/national quality standards, e.g. ISO 9000:2015 or international equivalent.

Types and impact of quality costs when manufacturing engineered components, including:

- internal failure
- external failure
- appraisal
- prevention.

### A2 Quality control

Essential parameters of quality control when manufacturing engineered components, including:

- types of inspection, e.g. pre-processing, in-process, completed components
- frequency of inspection, e.g. sampling, full batch
- documentation used, e.g. statistical charts, non-compliance reports
- provision for traceability, e.g. production records, batch labelling
- calibration, e.g. instrumentation (measuring equipment, comparator equipment, gauges), standards.

## Learning aim B: Know about dimensional tolerances and types of fit for engineered components

### B1 Tolerances and components

Principles of tolerances and types of fit, including:

- use of global/national quality standards e.g. British Standard (BS) 4500:2009 or international equivalent
- hole and shaft basis system
- International Organization for Standardization (ISO) system of limits and fits
- types of fit used in assembled components – clearance, transition, interference
- implications of non-compliance
- impact of applying types of fit.

Engineered components, including:

- components with both male and female parts.

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## Learning aim C: Use quality control equipment to monitor the quality of engineered components

### C1 Features to be measured or inspected

Component features to include:

- dimensional – length, diameter, depth, flatness, angle
- geometrical – profiles, roundness, accuracy of form
- surface texture/roughness.

### C2 Engineered components and engineering drawings

Components and assembled components with their engineering drawings that are suitable for measuring or inspecting for fitness for purpose:

- dimensional features, including tolerances
- geometric features
- surface texture/roughness.

### C3 Using measuring equipment

Types applicable to the component feature to be measured or inspected, including:

- micrometers, e.g. internal, external, depth
- steel rules
- vernier callipers
- vernier height gauge
- surface plate
- straight edge
- engineer's try-square
- bevel protractors
- combination sets
- roughness comparison specimens (Rubert gauges).

### C4 Using comparator equipment

Types applicable to the component feature to be measured or inspected, including:

- dial test indicators, e.g. plunger type, lever type
- simple mechanical comparators, e.g. inside calliper, outside calliper
- standard gauges, e.g. slip gauges, length bars, radius gauges, profile templates
- go and no-go gauges, e.g. plug gauges, gap gauges, taper plugs, ring gauges.

### C5 Engineered components

A range of engineered components that have dimensional, geometric and surface texture/roughness features, including:

- simple engineered components, e.g. turned shaft, connecting rod, angled pin, threaded bush, stepped milled block, drilled plate, clamp strap, bearing cover.


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## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Know about quality and quality control in engineering** | | |
| **A.P1** Describe the meaning of 'quality' in engineering.<br>**A.P2** Describe types of quality cost when manufacturing a quantity of an engineered component.<br>**A.P3** Describe the essential parameters of quality control when manufacturing a quantity of an engineered component. | **A.M1** Explain the impact of quality costs when manufacturing a quantity of an engineered component.<br>**A.M2** Explain, using examples, the essential parameters of quality control when manufacturing a quantity of an engineered component. | **A.D1** Evaluate undesirable and constructive quality costs and how the essential parameters of quality control are applied when manufacturing a quantity of a specific engineered component. |
| **Learning aim B: Know about dimensional tolerances and types of fit for engineered components** | | |
| **B.P4** Describe the principles of tolerances and types of fit.<br>**B.P5** Describe different types of fit between engineered components from given tolerance information. | **B.M3** Justify why tolerances and different types of fit are necessary when manufacturing and assembling engineered components. | **B.D2** Evaluate the application of tolerances and different types of fit to the manufacture and assembly of specific engineered components. |
| **Learning aim C: Use quality control equipment to monitor the quality of engineered components** | | |
| **C.P6** Describe different types of measuring and comparator equipment to be used when inspecting a given engineered component.<br>**C.P7** Use measuring and comparator equipment to inspect the dimensional, geometric and surface texture features of a given engineered component. | **C.M4** Justify the use of specific types of measuring and comparator equipment when inspecting a given engineered component.<br>**C.M5** Use measuring and comparator equipment with accuracy to inspect and record the dimensional, geometric and surface texture features of a given engineered component. | **C.D3** Evaluate the use of specific types of measuring and comparator equipment when inspecting and recording, with accuracy, the compliance of a given engineered component with reference to the engineering drawing. |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A and B (A.P1, A.P2, A.P3, A.M1, A.M2, A.D1)

Learning aim: B (B.P4, B.P5, B.M3, B.D2)

Learning aim: C (C.P6, C.P7, C.M4, C.M5, C.D3)

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# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a variety of engineered components with a full range of features as per B1 and C5 in the content (components and assembled components)
- appropriate global/national published quality standards, e.g. British Standards BS 4500:2009 or international equivalent
- a range of engineering drawings for engineered components that includes a full range of features as per C5 in the content
- a workshop environment and the full range of measuring and comparator equipment.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Evaluate costs of quality that are undesirable, having a negative impact, to those that are constructive, those in place to avoid further waste and cost, when manufacturing a quantity of engineered components and, using examples, evaluate how the parameters of quality control are used when applied to manufacturing a quantity of engineered components.
- The evaluation will be of sufficient detail to enable a non-engineer to understand which costs can be from activities that are investments to help with product reliability and how some may be first seen as waste.
- The evaluation will be accurate, for example when considering the need to calibrate equipment if higher level of precision equipment is needed to carry out the calibration and costly references back to standards are needed.

**For Merit standard**, learners will:

- Explain the impact of costs of quality when manufacturing a quantity of engineered components and, using examples, explain the parameters of quality control.
- The explanations will be of sufficient detail to enable a non-engineer to understand the impact and should include examples such as why sampling inspection is acceptable when making large quantities of standard nuts and bolts or why full batch inspection is necessary for small quantities of bespoke components.
- The explanations will be accurate, for example when referring to the impact of quality costs they will explain that prevention cost is an additional cost but it is likely that failure will be prevented from occurring, lessening the need to pay for breakdowns, which could also be dangerous. The explanations are not likely to have a conclusion.

**For Pass standard**, learners will:

- Describe the four aspects of quality: fitness for purpose, safe to use, meeting customer requirements, and standards such as ISO 9000:2015 or the international equivalent. It will also include appropriate descriptions of the costs of quality including internal and external failure, appraisal and prevention costs when manufacturing a quantity of engineered components.

- Describe the parameters of quality control including types and frequency of inspection, the documentation used, provision for traceability and calibration when manufacturing a quantity of engineered components.
- The descriptions will be of sufficient detail to enable a non-engineer to know about the terms used, what the costs of quality and the parameters of quality control are. The descriptions will be mostly accurate, for example when referring to calibration they will cover that equipment is checked on a regular basis for accuracy and functionality before it is used but will not indicate why.

## Learning aim B

To enable learners to achieve the requirements of this learning aim the engineered components considered should be taken from mechanical engineering assemblies and should cover all the types of fit. Good examples of clearance fits would be those used where a shaft is rotating in a bearing or something as simple as a hinge and its pin. Good examples of transition fits would be keys on a shaft or pulleys on a shaft, mainly assemblies where the opportunity to disassemble needs to be retained. Good examples of interference fits are those where permanent assemblies are required such as bushes that are bearings or a gear mounting onto a shaft which will be subjected to high torque levels.

**For Distinction standard**, learners will:

- Evaluate why tolerances and different types of fit are necessary when manufacturing and assembling engineered components; they will include a description of the full range of principles of tolerances based around the use of standards and the ISO system of limits and fits for both a hole and shaft basis. Consideration will be given to clearance, transition and interference fits from given assembly and tolerance information. This could be clearly shown using diagrams so a non-engineer can see and understand this need.
- The evaluation will be of sufficient detail to enable a non-engineer to see that with, say, a clearance fit, whatever the size of the male and the female parts, there will always be space between the two parts when fitting together, meaning the shaft will always go into the hole and can be used where a rotational motion is required. It should compare tolerances, for example components with tighter tolerances will need more precise manufacturing, such as grinding which is very expensive, and components with looser tolerances can be manufactured with no machining such as die casting. Different types of fit should be compared which should show the connection between close fits and high costs, loose fits and lower costs as well as the functional, designed need.

**For Merit standard**, learners will:

- Justify why tolerances and different types of fit are necessary when manufacturing and assembling engineered components; they will include a description of the full range of principles of tolerances based around the use of standards and the ISO system of limits and fits for both hole and shaft basis. Consideration will be given to clearance, transition and interference fits from given assembly and tolerance information. This could be clearly shown using diagrams so a non-engineer can see this need.
- The justification will be of sufficient detail to enable a non-engineer to see that with, say, a clearance fit, whatever the size of the male and the female parts, there will always be space between the two parts when fitting together, meaning the shaft will always go into the hole and can be used where a rotational motion is required.

**For Pass standard**, learners will:

- Describe the full range of principles of tolerances based around the use of standards and the ISO system of limits and fits for both hole and shaft basis. The description should include clearance, transition and interference fits from given assembly and tolerance information. This could be clearly shown using diagrams so a non-engineer can know what each looks like.
- The description will be of sufficient detail to enable a non-engineer to see that with, say, a clearance fit, whatever the size of the male and the female parts, there will always be space between the two parts when fitting together.

## Learning aim C

- To enable learners to achieve the requirements of this learning aim the engineered component considered should be given along with a drawing of the component that must include all the following:
  - the five-dimensional features (as defined by Topic C1 in the content section) including tolerances for each dimensional feature
  - the three geometrical features (as defined by Topic C1 in the content section)
  - a surface texture/roughness feature such as an Ra value
  - the requirement to use the full range of measuring (ten) and comparator (four) equipment (as defined by Topics C3 and C4 in the content section),

**For Distinction standard**, learners will:

- Evaluate the use of types of measuring and calibrating equipment when assessing the quality of their given engineered component. The evaluation should be sufficiently correct to enable a non-engineer to know what the equipment is, what it does and why it is the most suitable for giving the most appropriate results. For example, it is quick and easy to use a plug gauge to assess whether a hole is of an acceptable size for its application rather than taking longer to measure this feature with an internal micrometer to find its exact size. Knowing its exact size is of no additional benefit when monitoring the manufacturing process to establish if it is under control and producing useable components or not.
- Carry out measurements or inspection of a given engineered component containing dimensional features and tolerances and geometric and surface texture/roughness features. The activities should include the use of the full range of measuring and calibration equipment and engineering drawings of the components. Measurements and decisions should be accurate, and the learner observation record/witness statement should reflect this accuracy against the engineering drawings used, which could also be annotated to show this accuracy.

**For Merit standard**, learners will:

- Justify why the types of measuring and calibrating equipment are to be used when inspecting their given engineered component. The justifications should be sufficiently correct to enable a non-engineer to know what the equipment is, what it does and the accurate reasons for use.
- Carry out measurements or inspection of a given engineered component containing dimensional features and tolerances and geometric and surface texture/roughness features. The activities should include the use of the full range of measuring and calibration equipment and engineering drawings of the components. Measurements and decisions should be accurate, and the learner observation record/witness statement or annotated drawings should reflect this accuracy.

**For Pass standard**, learners will:

- Describe the types of measuring and calibrating equipment that is to be used when inspecting their given engineered component. The descriptions should be sufficiently correct to enable a non-engineer to know what the equipment is and what it does.
- Carry out measurements or inspection of a given engineered component containing dimensional features and tolerances and geometric and surface texture/roughness features. The activities should include the use of the full range of measuring and calibration equipment. Measurements and decisions may not always be accurate such as a slight misreading of an external micrometer leading to a decision that a turned shaft is out of tolerance.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 3: Investigating an Engineering Product
- Unit 8: Machining Techniques.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into quality, quality control and measuring and inspection activities and the continued importance of related activities to a range of engineering sectors
- documentation, such as a range of suitable engineering drawings and associated engineered components
- work experience, which will allow learners to become familiar with industrial quality control activities and the typical industrial environments in which they are used
- an engineering technician or supervisor to support practical lessons and to provide feedback and developmental advice to learners as their skills develop. This would help to ensure that the measurement and inspection activities are taught effectively and mirror those in current use in industry.



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## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate measuring and comparator equipment to carry out measuring and inspection of engineered components.

### Managing information

- Collecting, recording and interpreting quality control data from drawings.
- Using appropriate standards to extract tolerance and limits and fits data.

### Self-management and development

- Development of practical skills relating to measuring or inspection will be self-managed by learners.
- Safely and effectively self-managing the preparation and carrying out of measuring or inspection activities.

# Unit 17: 3D Printing

Level: **2**

Unit type: **Internal**

Guided learning hours: **60**

## Unit in brief

Learners will understand the technology and capabilities of the fused deposition modelling process and will design and produce a prototype component.

## Unit introduction

Did you know that fused deposition modelling (FDM), popularly known as 3D printing, is used by engineers all over the world to manufacture prototypes, customise products and to create assemblies in one operation? It can be used to manufacture components that it would be difficult to produce using traditional material removal or moulding processes. FDM is one of the most widely used additive manufacturing (AM) processes that are revolutionising the way we make artefacts.

In this unit, you will learn about the technology and capabilities of the FDM process.

This unit will also help you to understand and use the most appropriate methods to design and develop suitable prototype components through the use of a 3D CAD system. You will learn about the machines that you are likely to use, how to transfer a 3D CAD model to an FDM system and how to manufacture a prototype component.

Importantly, this unit will make you aware of how important it is that you generate 3D CAD models that can be easily understood by FDM machines (and also other engineers) so there is no chance of misinterpretation.

## Learning aims

In this unit you will:

**A** Examine the technology and capability of the fused deposition modelling (FDM) process

**B** Investigate component design to effectively use fused deposition modelling

**C** Develop a prototype component using fused deposition modelling safely.

## Summary of unit

<table>
<tr><th>Learning aim</th><th>Key content areas</th><th>Assessment approach</th></tr>
<tr><td>A Examine the technology and capability of the fused deposition modelling (FDM) process</td><td>A1 Technology of the FDM process<br>A2 Capability of the FDM process</td><td rowspan="2">A report, complete with annotated diagrams and images, detailing the technology and capability of the FDM process to produce a prototype component, and how the FDM process allows the design to be improved, and is more appropriate than traditional manufacturing processes.</td></tr>
<tr><td>B Investigate component design to effectively use fused deposition modelling</td><td>B1 Component design for the FDM process<br>B2 Traditional manufacturing processes</td></tr>
<tr><td>C Develop a prototype component using fused deposition modelling safely</td><td>C1 Designing a prototype component for the FDM process<br>C2 Manufacture of a prototype component using the FDM process</td><td>The finished 3D print and a portfolio with safety notes, 3D CAD drawings, output of the data transfer programme, annotated photographs and/or videos with learner narration, images and diagrams and learner observation records/witness statements.</td></tr>
</table>

## Content

### Learning aim A: Examine the technology and capability of the fused deposition modelling (FDM) process

#### A1 Technology of the FDM process

- Components of a 3D FDM printer:
  - build platform
  - extrusion nozzle
  - extruder
  - heater
  - thermistor or thermocouple
  - stepper/servo-motor
  - gears.
- FDM process:
  - 3D model created on a CAD software package
  - image created in a photo-editing software package
  - component scanned in three dimensions and uploaded into a CAD or photo-editing software package
  - process the 3D CAD model or photo-edited image into a file suitable for manufacturing on a FDM system – AMI (amazon machine image), standard tessellation language (STL), drawing interchange format (DXF)
  - data transfer – CAD to a programming language (AMI, STL or DXF), resolution within machine parameters, transfer rate and memory size, resolution of tessellation and facets.
- Materials for FDM:
  - polymers – acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), high-impact polystyrene (HIPS), thermoplastic polyurethane (TPU), aliphatic polyamides (nylon).
- Extrusion process:
  - layers
  - X, Y, and Z coordinates
  - filament feed
  - deposition
  - vertical and horizontal movement
  - stringing
  - continuous filament.
- Safety:
  - control of substances hazardous to health – manufacturers' safety data sheets, hazard symbols, protection from contact with hazardous substances
  - personal protective equipment (PPE) – eye protection, heat-resistant apparatus, gloves, protective clothing
  - safety hazards – handling materials such as polymer wire and polymer powders and high temperatures.

#### A2 Capability of the FDM process

- Capacity:
  - component size is limited by the capacity of the FDM machine
  - physical machine footprint and base size

  - working area
  - stepping (aliasing)
  - surface finish with regards to resolution
  - accuracy within machine parameters
  - resolution within machine parameters
  - processing time considerations to achieve the desired quality and resolution.
- Application:
  - personalised fabrication, customisation, personal products, home and machine repairs
  - biomedical, dental, prosthetics, hearing aids and human tissue
  - rapid prototyping of products and components
  - manufacture of assembled items that cannot be manufactured together using traditional processes without multiple operations
  - reduced time to manufacture as specialist tooling (jigs, fixtures, moulds etc.) are typically not required
  - reduction in mass
  - slow process speed, high part cost.
- Environmental factors:
  - recycling of polymer-based materials
  - limited waste material is produced as a result of the process
  - less energy is required to manufacture components
  - localisation of manufacturing reduces the need for transportation.
- Prototype components that can fit into an existing component or assembly:
  - gears
  - housings
  - support strut
  - bush
  - con rod
  - flywheel
  - spacers.

## Learning aim B: Investigate component design to effectively use fused deposition modelling

### B1 Component design for the FDM process

- FDM design and manufacturing considerations:
  - single or multiple materials
  - single or multiple colours
  - sections needing support during manufacture
  - support of overhanging surfaces
  - structural integrity – layer structure
  - cooling of the finished product – shrinkage allowance
  - surface finish with regards to resolution
  - accuracy within machine parameters
  - processing time considerations to achieve the desired quality and resolution
  - functionality of the product
  - program file size
  - transfer of data – Wi-Fi, direct link, SD card.



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### B2 Traditional manufacturing processes

- Limitations of traditional processes such as turning, milling, drilling and moulding:
  - multiple operations
  - skilled operators required
  - assembly required
  - greater energy use
  - jigs and fixtures required
  - specialist machine tools
  - component design limited by the capability of the process
  - component design limited by the complexity of form that can be achieved
  - component design limited by the need to remove material or mould to shape.

## Learning aim C: Develop a prototype component using fused deposition modelling safely

### C1 Designing a prototype component for the FDM process

- Examples of irregular-shaped components that can fit into an existing component or assembly:
  - bracket
  - retaining clip
  - interchangeable screwdriver tip
  - support strut
  - retaining plate
  - Allen key
  - Allen key (wrench) holder
  - flywheel
  - open ended spanner
  - spanner rack
  - ratchet.
- Examples of components that include hollow sections that can fit into an existing component or assembly:
  - drill bit holder
  - drill gauge
  - bush
  - socket
  - nozzle
  - valve
  - slip on phone case
  - USB/flash drive case.
- Creation of a 3D component drawing suitable for transfer to a FDM system:
  - configure a 3D CAD system – origin, units, snap, grid, coordinate system, file types, filing systems
  - 3D model created on a CAD software package – suitability for printing, correct orientation, size, scale
  - 3D model geometry – faces, edges, vertices
  - shell command for hollowing a component
  - revolve command for a symmetrical rotational component
  - extrude command to extend a product along the Z axis

- stepping (aliasing)
- adequate support to prevent distortion
- limitation of strings
- bridging
- process the 3D CAD model or photo-edited image into a file suitable for manufacturing on an additive system
- data transfer – CAD to a programming language, resolution within machine parameters, transfer rate and memory size.

**C2 Manufacture of a prototype component using the FDM process**

- Component and FDM machine set-up:
  - checking on-screen representations and simulations
  - physical size, scale and datum
  - single or multiple materials, binders, fillers and support structures
  - correct component orientation
  - parameters during operation – infill, layer height, feed rate, travel feed rate, temperature, resolution, extruder retraction
  - removal of stringing, support materials – sniping, sanding, dissolving.
- Safe working practices:
  - personal protective equipment (PPE) – overalls, safety glasses, safety boots
  - use of machine guards.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Examine the technology and capability of the fused deposition modelling (FDM) process</td><td rowspan="4">AB.D1 Evaluate the use of fused deposition modelling and its impact on the initial design and manufacture of a prototype component.</td></tr>
<tr><td>A.P1 Describe how the fused deposition modelling process works.</td><td>A.M1 Discuss how fused deposition modelling is used to manufacture a prototype component.</td></tr>
<tr><td colspan="2">Learning aim B: Investigate component design to effectively use fused deposition modelling</td></tr>
<tr><td>B.P2 Explain why the use of fused deposition modelling allows the design of a component to be improved.</td><td>B.M2 Discuss how the use of fused deposition modelling allows the initial design of a prototype component to be adapted.</td></tr>
<tr><td colspan="2">Learning aim C: Develop a prototype component using fused deposition modelling safely</td><td rowspan="2">C.D2 Optimise the development of a prototype component safely and effectively using fused deposition modelling.</td></tr>
<tr><td>C.P3 Design a prototype component that can be produced safely using fused deposition modelling<br>C.P4 Produce a prototype component safely using fused deposition modelling.</td><td>C.M3 Develop a prototype component safely and accurately using fused deposition modelling.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, A.M1, B.M2, AB.D1)

Learning aim: C (C.P3, C.P4, C.M3, C.D2)



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# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a 3D CAD facility, including computers loaded with appropriate 3D software such as TurboCAD Deluxe, Sketch up, AutoCAD, AutoCAD Inventor, Solidworks or Draftsight Professional
- a file transfer system to process the 3D CAD model into a comprehensible file for the FDM printer
- a fused deposition modelling (FDM) printer
- reference material such as manufacturers' catalogues and technical reference materials for the FDM system in use
- examples of 3D CAD drawings suitable for creating a printed model
- examples of finished 3D printed models.

## Essential information for assessment decisions

For the assessment activity for learning aims A and B, learners must be provided with the details of a solid, prototype ABS component that would benefit from a reduction in mass without it affecting its fitness for purpose.

Learners must be provided with an engineering drawing showing the features and dimensions of the prototype component, as well as information about its purpose.

With reference to component design, learners do not need to consider topology optimisation.

## Learning aims A and B

**For Distinction standard**, learners will:

- Evaluate fused deposition modelling technology and its capability to produce the solid, prototype ABS component. The learner response will cover printer components, the extrusion process, safety, capacity and environmental considerations. For example, the learner will give justified reasons as to why FDM is more appropriate and suitable than traditional processes to manufacture the component.
- Evaluate the impact of the use of FDM on the initial design and manufacture of the solid, prototype ABS component. The learner response will cover design and manufacturing considerations and traditional manufacturing processes. For example, the learner will detail how the design of the component could change if using FDM rather than traditional processes and how that may result in a reduction in mass during manufacture, meaning that less materials are used.

**For Merit standard**, learners will:

- Discuss fused deposition modelling technology and its capability to produce the solid, prototype ABS component. The learner response will cover printer components, the extrusion process, safety, capacity, and environmental considerations. For example, the learner will give reasons such as the limitations and benefits as to why FDM is more suitable than traditional processes to manufacture the component.

- Discuss the impact of the use of FDM on the initial design and manufacture of the solid, prototype ABS component. The learner response will cover some design and manufacturing considerations and traditional manufacturing processes. For example, the learner will detail how the design of the component may possibly change if using FDM rather than traditional processes and how that may result in a reduction in mass whilst maintaining its fitness for purpose.

**For Pass standard**, learners will:

- Describe the fused deposition modelling technology. The learner response will cover most printer components, the extrusion process, safety, capacity and environmental considerations. For example, the learner will give a description of the suitability of FDM to manufacture a component.
- Describe the use of FDM on the initial design and manufacture of a component. The learner response will cover some design and manufacturing considerations and traditional manufacturing processes. For example, the learner will detail how the design of the component might have some changes if using FDM rather than traditional processes.

## Learning aim C

For the assessment activity for learning aim C, learners must design (using CAD) and produce a prototype component that is an irregular shape and/or includes a hollow section (see the examples in C1), using fused deposition modelling. The prototype component must be able to fit into an existing component or assembly, so its accuracy can be checked.

**For Distinction standard**, learners will:

- Demonstrate compliance with safe working practices at all times.
- Produce and optimise an accurate 3D CAD model of the prototype component.
- Independently process the 3D CAD model to create a file and successfully transfer it to the FDM printer.
- Analyse the on-screen representation to remove errors and to optimise the manufacturing of the component, for example to improve accuracy and surface finish and to reduce processing time.
- Independently and accurately set-up the FDM printer.
- Produce an irregularly shaped or a hollow component by monitoring the operational parameters to ensure accuracy and compliance.
- Produce an irregularly shaped or a hollow component as a one-piece component, not by creating several pieces and adhering them together, and remove all strings and supports.
- Confirm that the printed component fits well into an existing component or assembly.

**For Merit standard**, learners will:

- Demonstrate compliance with safe working practices at all times.
- Produce an accurate 3D CAD model of the prototype component.
- Process the 3D CAD model to create a file and transfer it to the FDM printer.
- Check the on-screen representation to remove most errors to manufacture the component, for example to identify any required supports.
- Accurately set-up the FDM printer.

- Produce an irregularly shaped or a hollow component by monitoring the operational parameters to ensure accuracy.
- Produce an irregularly shaped or a hollow component as a one-piece component, not by creating several pieces and adhering them together, and remove all strings and supports.
- Confirm that the printed component fits well into an existing component or assembly.

**For Pass standard**, learners will:

- Demonstrate compliance with safe working practices at all times.
- With support produce a 3D CAD model of the prototype component.
- With support process the 3D CAD model to create a file and to transfer the file to a FDM printer.
- With support check the on-screen representation to remove some errors to manufacture the component, for example to identify non-aligned surfaces.
- With support set-up the FDM printer.
- Produce an irregular shaped or a hollow component by monitoring the operational parameters.
- Produce an irregular or a hollow component that may be created using multi-pieces and adhering them together and remove some strings and supports.
- Confirm that the printed component approximately fits into an existing component or assembly.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 26: Robotics
- Unit 27: General Programming.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest or partner speakers from industry to discuss the importance of design, 3D CAD and AM processes in engineering with examples of drawings and 3D models
- visits to industrial workshops to encounter real-life working practices using AM processes and procedures
- work experience, which will allow learners to become much more familiar with industrial engineering environments and the way that AM processes are set-up and operated.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Creating appropriate designs suitable for the FDM process and appropriate approaches to carry out engineering work activities.

### Managing information

- Interpreting drawings, information, instruction manuals and programmes.

### Self-management and development

- Safely and effectively self-managing the preparation and carrying out of engineering work activities.

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# Unit 18: Applied Chemistry for Engineers

Level: **2**
Unit type: **Internal**
Guided learning hours: **30**

## Unit in brief

Learners will be introduced to the fundamentals of chemistry and some important applications of chemical and electro-chemical processes in engineering.

## Unit introduction

In this unit you will gain a knowledge and understanding of the chemistry that underpins a number of engineering applications.

It is important that engineers understand the fundamentals of chemistry. These are the building blocks that make up everything from the simple hydrogen molecule to the large complex hydrocarbons found in crude oil. This unit starts by looking at the atom, the elements, the Periodic Table and the ways in which atoms are able to bond together. We will look at how these different types of bonds give chemical substances their physical properties from tensile strength to electrical conductivity.

Chemistry can be seen in action across all forms of engineering, from the chemical processes involved in rust formation to the electro-chemical processes that take place in batteries. This unit provides the opportunity to explore industrial and engineering applications of chemistry in depth using case studies and real-life examples. Of course, chemical processes often produce undesirable by-products or waste that can have a negative impact on the environment so it's also important to understand how these can be managed.

As an engineer, it is important to understand the basics of chemistry and industrially important chemical processes. This unit helps to prepare you for employment, for a traineeship/apprenticeship or for further study in engineering.

## Learning aims

In this unit you will:

**A** Investigate the atomic structure and the types of chemical bonds found in common substances

**B** Understand the engineering applications of some chemical and electro-chemical processes.

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## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate the atomic structure and the types of chemical bond found in common substances | **A1** The Periodic Table<br>**A2** Atomic structure<br>**A3** Chemical bonding<br>**A4** Properties of ionic, covalent and metallic materials | Report based on working with the Periodic Table to identify elements and determine their structure, and the results of tests on the physical properties of substances to determine the type of chemical bonding. |
| **B** Understand the engineering applications of some chemical and electro-chemical processes | **B1** Chemical processes<br>**B2** Electro-chemical processes | Report evaluating the use of one chemical and one electro-chemical process in an engineering context. |



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# Content

## Learning aim A: Investigate the atomic structure and the types of chemical bond found in common substances

### A1 The Periodic Table

Elements and the structure of the Periodic Table

- Definition of an element, symbols and names of elements.
- Definitions including atomic number, mass number, group, period, metals and non-metals.
- Common elements encountered in engineering applications including:
  - combustion, e.g. carbon, hydrogen, oxygen.
  - batteries, e.g. zinc, chlorine, lead
  - inert gases e.g. argon. Metals e.g. iron, copper, zinc, aluminium.
- Position in the Periodic Table of common metal and non-metal elements used in engineering applications. Physical properties of non-metals e.g. poor conductors, brittle, low melting point, often liquids or gases at room temperature. Physical properties of metals e.g. reflective/shiny, good conductors, malleable and ductile, high melting point, most solid at room temperature.
- Elements, mixtures and compounds.

### A2 Atomic structure

The structure of atoms, molecules and ions

- Definitions including atom, molecule, ion
- The structure of atoms: nucleus, electrons, protons, neutrons, electronic structures of metals and non-metals.
- Isotopes

### A3 Chemical bonding

Definitions and structures of ionic, covalent and metallic bonding.

- Ionic bonding, transfer of electrons, from metal atom(s) to non-metal atom(s) to form ions, electronic structures and formulae representations of simple examples, electrostatic attraction.
- Covalent bonding, sharing of electrons between non-metal atoms, electronic structures and formulae representations of simple examples. Allotropes such as diamond and graphite.
- Metallic bonding, between metal ions, lattice of positively charged metal ions with delocalised electrons.
- Use of dot and cross diagrams to describe the structure of covalent and ionic bonding.

### A4 Properties of ionic, covalent and metallic materials

Physical properties and tests to distinguish between ionic, covalent and metallic bonded substances.

- Ionically bonded compounds – high melting and boiling points, soluble in polar liquids such as water and insoluble in non-polar liquids, conduct electricity when molten or in solution.

- Covalently bonded molecules and compounds – low melting and boiling points, soluble in non-polar liquids such as organic solvents and usually insoluble in polar liquids, do not conduct electricity.
- Metallic bonding – usually high melting and boiling points, good conductors of heat and electricity, high tensile strength and malleability, increase in electrical resistance with increasing temperature.

## Learning aim B: Understand the engineering applications of some chemical and electro-chemical processes

### B1 Chemical processes

Operation, characteristics, safety and environmental impact of common chemical processes encountered in engineering.

- Material degradation – mechanisms, chemical equations and effects of material degradation processes including: corrosion in steel (rusting), corrosion resistance, UV degradation of polymers, corrosive effects of acids and alkalis.
- Acid etching – common acids e.g. ferric chloride, hydrochloric acid, nitric acid, sulphuric acid, apparatus, principle of operation, chemical equations and waste products involved in engineering applications including PCB manufacture and etching metals.
- Combustion – chemical equations, products of combustion/partial combustion, effects on the environment in engineering applications including gasoline internal combustion engine, hydrogen internal combustion engine, gas fired power stations.

### B2 Electro-chemical processes

The electro-chemical series (activity series) – table of elements according to their predicted chemical activity with regard to the loss of their outer electrons in comparison with hydrogen in an electrical cell.

Operation, characteristics, safety and environmental impact of common electro-chemical process encountered in engineering.

- Cells – chemical components, electrolytes, structure, principle of operation and any chemical equations involved in engineering applications including: zinc chloride batteries, lead acid batteries, hydrogen fuel cells, solar cells.
- Electrolysis – chemical components, apparatus, principle of operation, chemical equations and waste products involved in engineering applications including: extraction of aluminium, anodising aluminium.
- Electroplating – chemical components, apparatus, principle of operation, chemical equations and waste products involved in engineering applications including: silver plating, chrome plating.
- Electrolytic corrosion – chemical components, common electrolytes, principle of corrosion, chemical equations, effects in an engineering context and prevention including: aluminium in contact with steel, copper in contact with steel, zinc in contact with steel.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate the atomic structure and the types of chemical bonds found in common substances** | | **A.D1** Compare the structure of metallic and non-metallic elements, the structure of metallic, covalent and ionic chemical bonding and their effects on the physical properties of chemical substances. |
| **A.P1** Identify at least three metallic and three non-metallic elements given their atomic structure using the Periodic Table.<br>**A.P2** Identify metallic, covalent and ionic chemical bonding from given physical properties of chemical substances. | **A.M1** Describe the structure of metallic and non-metallic elements, the structure of metallic, covalent and ionic chemical bonding and the effect of bond type on the physical properties of chemical substances. | |
| **Learning aim B: Understand the engineering applications of some chemical and electro-chemical processes** | | **B.D2** Evaluate an engineering application of a chemical and an electrochemical process. |
| **B.P3** Describe an engineering application of a chemical process.<br>**B.P4** Describe an engineering application of an electro-chemical process. | **B.M2** Explain an engineering application of a chemical and an electro-chemical process. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.

The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.D2)

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# Further information for teachers and assessors

## Resource requirements

There are no special resources needed for this unit.

## Learning aim A

**For Distinction standard**, learners will:

- Compare the electron structure of metallic and non-metallic elements using information from the Periodic Table. Identify key differences between the two and their effect on the type of chemical bonds formed when they are joined in chemical substances (i.e. the types of bonds formed between two metallic atoms, two non-metallic atoms and between a metallic and a non-metallic atom).
- Compare the structures of metallic, covalent and ionic bonds using appropriate sketches and “dot and cross” diagrams and relate these structures to their contrasting physical properties (e.g. conductivity as a solid, molten and in solution, melting point, solubility etc).

**For Merit standard**, learners will:

- Describe the electron structure of metallic and non-metallic elements using information from the Periodic Table.
- Describe the structures of metallic, covalent and ionic bonds using appropriate sketches and “dot and cross” diagrams and relate these structures to physical properties (e.g. conductivity as a solid, molten and in solution, melting point, solubility etc).

**For Pass standard**, learners will:

- Identify at least three metallic and three non-metallic elements from details of their atomic structure (i.e. number of protons, neutrons and electrons) using information from the Periodic Table.
- Identify substances containing metallic, covalent and ionic chemical bonding from given physical properties (e.g. if a solid chemical substance is a good conductor of electricity, is malleable and shiny then it is metallic and contains metallic bonding).

## Learning aim B

**For Distinction standard**, learners will:

- Evaluate the use, relative importance, safety and environmental impact of one chemical and one electro-chemical process. This will be based on a detailed explanation of the industrial application of each process, its use and its importance in an engineering context. It will include detailed explanations of the apparatus, equipment and/or machinery involved, annotated diagrams/photographs and explanatory notes covering principles of safe operation, energy requirements and dealing with waste.
- Provide balanced chemical equations to help explain the chemistry involved in both processes and how the required reaction or reactions produce the required output, including by-products and waste. Further chemical equations will be included where relevant to explain the impact of any waste products released into the environment. The effects of these pollutants and how they are minimised or controlled will be included in the wider evaluation of the two processes.

**For Merit standard**, learners will:

- Explain the use, safety and environmental impact of one chemical and one electro-chemical process. This will include: a detailed explanation of the industrial application of each process, its use and its importance in an engineering context, detailed explanations of the apparatus, equipment ~and/or machinery involved, annotated diagrams/photographs and explanatory notes covering principles of safe operation, energy requirements and dealing with waste.
- Provide chemical equations to help explain the chemistry involved in both processes and how the chemical reaction or reactions produce the required output, including by-products and waste. Further chemical equations will be included where relevant to help explain the impact of any waste products released into the environment.

**For Pass standard**, learners must:

- Describe the use, safety and environmental impact of one chemical and one electro-chemical process. This will include: a detailed description of the industrial application of each process, its use in an engineering context, descriptions of the apparatus, equipment and/or machinery involved, annotated diagrams/photographs describing safe operation, energy requirements and dealing with waste.
- Provide chemical equations to describe the chemistry involved in both processes and how the chemical reaction or reactions produce the required output, including by-products and waste.

## Links to other units

This unit links to, for example:

- Unit 5: Mathematics for Engineering Technicians
- Unit 19: Data Capture and Interpretation.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest or partner speakers from industry
- visits to industrial workshops to encounter real-life working practices
- work experience, which will allow learners to become much more familiar with industrial engineering environments.

# Unit 19: Data Capture and Interpretation

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will develop an understanding of how data capture is used to monitor and improve products and processes and will carry out an investigation to log data and analyse the results.

## Unit introduction

Have you ever thought about how data is captured and used by engineers? Whether it is the pressure inside a gas storage tank, the internal temperature of part of an aeroplane engine or the air flow over the body of a racing car, engineers need to collect and use large amounts of data to make sure that products, machinery and systems function as intended.

Data can be captured in real-time and transmitted to a base computer, for example telemetry from a vehicle. Or data can be captured by a data logger, which may record conditions (such as vibrations and heart rate) and physical quantities (such as temperature and electric current) over a period of time.

In this unit you will look at different uses of data loggers, including how they can be used to collect large amounts of useful data. You will look at how the data that has been collected can be analysed and presented to an audience. Finally, you will plan and carry out a data capture activity. You will use a data logger and sensors to collect data related to an engineering problem, and then analyse the data to present the results of your investigation to others.

## Learning aims

In this unit you will:

**A** Investigate data logging applications and technology used in industry

**B** Investigate statistical techniques and data representation approaches used to analyse data

**C** Undertake a data logging activity and analyse the results.

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## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate data logging applications and technology used in industry | **A1** Applications of data logging<br>**A2** Data logging technology | A report with annotated images/diagrams/photographs detailing the use of data logging and statistical techniques for engineering applications. |
| **B** Investigate statistical techniques and data representation approaches used to analyse data | **B1** Statistical techniques<br>**B2** Data representation approaches | |
| **C** Undertake a data logging activity and analyse the results | **C1** Completing a digital data logging activity<br>**C2** Practical application of data logging in engineering<br>**C3** Analysis of results | A practical activity to plan, carry out and analyse the results of a data logging activity.<br>The assessment evidence will include a plan, annotated photographs, learner observation records/witness statements and a written report that analyses the results. |



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# Content

## Learning aim A: Investigate data logging applications and technology used in industry

### A1 Applications of data logging

Learners will understand the applications and purpose of digital data logging and the types of data collected including the benefits and drawbacks of each one.

- Applications of digital data logging, including:
  - industrial applications: monitoring the condition of a machine (e.g. vibration and temperature), food storage
  - automotive/aerospace industry: car engine and jet engine performance, flight data recorder
  - environmental applications: to measure weather, soil conditions, traffic conditions
  - healthcare: heart rate, blood pressure, temperature, storage of medicines.
- Purpose of common data logging applications, e.g.:
  - to monitor the condition or performance of a machine/process
  - to collect and record parameters from a machine/process, and
  - to monitor/manage the health of individual people.
- Types of data
  - primary data – information collected directly from source
  - secondary data – information collected by a third party
  - big data
    - big data and how it is collected and used
    - sources of big data, e.g.: traffic sensors, ATM/cash machines, mobile phone networks, weather, digital television, aircraft engines, vehicle telematics.

### A2 Data logging technology

- Function and use of input devices:
  - Sensors, e.g. temperature, sound, light, movement, voltage, current, conductivity, position, speed, strain
  - pulse counters.
- Function and use of output devices:
  - digital data loggers, e.g.:
    - miniature single input loggers
    - Raspberry Pi Pico, or Arduino Uno
    - multi-channel
    - modbus
    - handheld portable
  - format of data, e.g.: Extensible Markup Language (XML), JavaScript Object Notation (JSON), YAML Ain't Markup Language (YAML)
  - computers for data analyis:
    - dashboard software, user interface
    - mobile phone applications.
- Parameters including:
  - sampling rate
  - accuracy/precision of the measurements
  - battery life.

- Methods of data transfer including:
  - network and storage: Ethernet, Wi-Fi, Bluetooth, cloud storage, Radio Frequency Identification (RFID)
  - data transfer methods: USB, memory card
  - semantic web.

### Learning aim B: Investigate statistical techniques and data representation approaches used to analyse data

#### B1 Statistical techniques

- Use of spreadsheets to analyse data, including:
  - import of CSV data from a data logger or external data source
  - classification of data
  - cross-tabulation of data
  - data patterns including:
    - averages: mean, median, mode
    - frequency, totals and counts
    - minimum and maximum values
    - percentages.
- Types of analysis, including:
  - regression analysis
  - factor analysis
  - cluster analysis
  - time series analysis including:
    - trends
    - seasonality
    - cyclic patterns.
- Benefits of statistical techniques, e.g. the use of regression analysis to determine the strength of the relationship between two or more variables, use of regression analysis to predict future conditions of systems.

#### B2 Data representation approaches

- Features of collected data, including:
  - size of sample
  - type of data in the sample
  - methods used to collect data
  - where the data was collected
  - when the data was collected.
- Graphical presentation methods for data including:
  - graphs: line graphs (straight and curved)
  - charts: pie chart, scatter diagrams, bar charts
  - tables: pivot table, frequency tables.
- Benefits of different ways to represent data, e.g. for ease of interpretation, clarity of information for third parties, to identify patterns and anomalies in data.

## Learning aim C: Undertake a data logging activity and analyse the results

### C1 Completing a digital data logging activity

- Stages of a data logging activity:
  1. identify what needs to be measured
  2. identify inputs
  3. safe set up of data logging equipment
  4. collection of data: number of readings, frequency of readings, length of investigation
  5. storage of data: internal memory, memory cards, USB drives
  6. transfer of data: Wi-Fi, Bluetooth, memory card, USB
  7. analysis of data.
- Health and safety precautions, e.g. isolating machines/equipment before use, using personal protective equipment, using low-voltage and low-pressure equipment and using appropriate guarding.

### C2 Practical application of data logging in engineering

- Measure of battery life over time using a voltage sensor.
- Capacitor discharge using voltage and current sensors.
- Ohm's law using voltage and current sensors.
- Extension of a spring using a position sensor.
- Weather using light, humidity and temperature sensors.

### C3 Analysis of results

Learners will analyse the data and draw conclusions from the data set.

- Interpretation of data, including:
  - trends
  - patterns
  - anomalies
  - possible errors.
- Drawing conclusions including:
  - relationships between collected data
  - comparison with theoretical results or expected outcomes
  - summarising results.
- Presenting analysed data including:
  - tables
  - graphical representations
  - presentation of data to an audience
  - application of appropriate scientific methods, e.g. independent/dependent variables, units, scale, lines (straight and curved) of best fit, grouping of data and identification of outlier data points.

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## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Investigate data logging applications and technology used in industry</td><td rowspan="4">AB.D1 Evaluate the purpose and use of data loggers and input and output devices for two different data logging applications, and the statistical techniques and data representation approaches used to analyse the data sets.</td></tr>
<tr><td>A.P1 Describe adequately the purpose and types of data associated with two different data logging applications.<br>A.P2 Describe adequately the functions of data logger input and output devices for two different applications.</td><td>A.M1 Describe in detail and accurately the purpose, types of data and functions of input/output devices for two different engineering applications, giving reasons for the use of the input and output devices selected.</td></tr>
<tr><td colspan="2">Learning aim B: Investigate statistical techniques and data representation approaches used to analyse data</td></tr>
<tr><td>B.P3 Describe adequately how statistical techniques are used to analyse two different data sets.<br>B.P4 Describe adequately the features of the data and the presentation method used for two different data sets.</td><td>B.M2 Describe in detail and accurately how statistical techniques and data representation approaches are used to analyse two different data sets, identifying the resultant benefits.</td></tr>
<tr><td colspan="2">Learning aim C: Undertake a data logging activity and analyse the results</td><td rowspan="2">C.D2 Interpret thoroughly, by referencing theoretical outcomes, the results from a data logging activity, effectively and accurately presenting the data using a scientific approach for the intended audience.</td></tr>
<tr><td>C.P5 Complete an engineering-based data logging activity safely.<br>C.P6 Interpret some of the results from a data logging activity using basic graphical and tabular methods.</td><td>C.M3 Interpret the results appropriately from a data logging activity, accurately presenting the data for the intended audience.</td></tr>
</table>



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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, B.P4, A.M1, B.M2, AB.D1)

Learning aim: C (C.P5, C.P6, C.M3, C.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners will need access to:

- digital data loggers as required by the learning aims and the *Content* section
- input and output devices as required by the learning aims and the *Content* section
- a range of equipment, materials, circuits and systems from which to collect data.

## Essential information for assessment decisions

## Learning aims A and B

**For Distinction standard**, learners will:

- Evaluate the use and purpose of data loggers for two different engineering applications, for example justifying the use of a multi-channel data logger for recording values of temperature and wind speed for a remote weather station. They will consider the operating parameters of the data logger and also ways in which data is transferred from the data logger.
- Write about primary, secondary and big data in the context of the engineering data logging applications they are evaluating, including the benefits and drawbacks of each when analysing the results of an investigation.
- Evaluate the use of specific types of input and output device, for example the use of a voltage sensor with a given operating range, and their use within a particular data logging application, for example for monitoring the life span and output voltage of a car battery over a period of time.
- Evaluate the use of statistical techniques to analyse data collected from a data logging investigation, including the use of big data, for example by explaining how a data set can be analysed to identify features such as minimum and maximum values, and then compared to big data sources that are available for similar investigations and data logging exercises.
- They will also evaluate the way data has been represented. For example, the use of graphical and tabular methods for presenting the outcomes of data logging activities, including different forms of data, and the significance of features of the collected data in the reporting of outcomes.

**For Merit standard**, learners will:

- Describe in detail and accurately the purpose of using data loggers for two different engineering applications and the different types of data that are associated with data logging. For example, by describing within an engineering context the features of primary data collected directly from a source and secondary data obtained from a third party and why such data is required.
- Describe in detail and accurately the function of at least two input devices and an output device that are used with data loggers in an engineering context. They will include reasons why the use of input/output devices is suitable for each application, for example why temperature sensors within an aircraft engine are appropriate for monitoring the performance of the engine in flight or why a battery operated miniature single input logger is appropriate for use in a refrigerated vehicle that is carrying fresh food.

- Describe in detail and accurately the use of the statistical techniques and representation of data used to analyse data sets from two different engineering applications. They will also identify the benefits of the approaches used. For example:
  - how data can be organised and analysed to identify how frequently the oil temperature in a car engine reaches a certain level and whether or not there is a pattern to it happening over time
  - using graphical methods to represent trends in oil consumption in a vehicle engine, which can then be used to determine if more frequent servicing of the vehicle is needed.

**For Pass standard**, learners will:

- Describe adequately the purpose and different types of data that are used with two different data logging applications. For example, by describing adequately that the purpose of monitoring a machine is to identify potential faults before they happen to allow preventative maintenance to take place, and the features of primary data collected directly from the source and secondary data obtained from a third party.
- Describe adequately the function of at least two input devices and an output device that are used with data loggers in each application. The adequate descriptions will be specific to their use with data loggers and will be mostly accurate, for example when referring to a current sensor they may refer to their ability to measure both alternating current (AC) and direct currents (DC) but may not mention that it can be used in combination with other sensors for more complex investigations.
- Describe adequately the use of statistical techniques for analysing data sets. For example, by describing how data collected from traffic sensors can be used to find the total number of vehicles on a particular road or how traffic flow trends can be identified from the data over time, such as over one day and a period of a week or year.
- Also, adequately describe the features of data, such as the size and type of sample, and ways in which a data set can be presented, for example using pie charts to indicate frequencies of values, or line graphs to identify trends.
- Overall adequate descriptions may contain some omissions and/or inaccuracies, however the descriptions will be relevant to the situations given.

## Learning aim C

**For Distinction standard**, learners will:

- Plan a data logging activity, selecting the most appropriate input devices for the values to be measured and frequency of readings to ensure that the data collected has an appropriate range to allow it to be analysed, taking into account theoretical or expected outcomes.
- Competently set up and safely carry out a data logging activity. They will show the capability to set up the input and an output devices with accuracy, and to check that the equipment is functioning correctly.
- Download and interpret the data collected using the data logger. They will generate detailed and accurate records of the results to show statistical information such as trends, ranges and frequency as appropriate. Scientific method should be used, for example independent variables, and all graphical information should be presented with an appropriate scale, labels, values and a title.

- Interpret the results they obtained against those that would be expected from theoretical outcomes or expectations, for example the time constant for a capacitor based on the time taken for the capacitor to discharge and making reference to the expected theoretical value, and present these in a suitable format that can be easily understood by a third party.

**For Merit standard**, learners will:

- Plan a data logging activity, selecting suitable input devices for the values to be measured and a frequency of readings that will allow the data collected to have a range of values that can be analysed.
- Set up and safely carry out a data logging activity, demonstrating a good level of skill. They will show the capability to set up the input and output devices with some accuracy, although these might not fully match those stated in the plan.
- Download and interpret the data collected using the data logger. They will generate complete records of the results to show trends and patterns in the data.
- Present the results of their investigation clearly and accurately, in both tabular and graphical format, in a way that can be understood by the intended audience.

**For Pass standard**, learners will:

- Plan a data logging activity, selecting input and output devices and a frequency of readings. These might not be fully appropriate, but would allow a suitable data set to be collected for the investigation.
- Set up and safely carry out a data logging activity demonstrating some skill. They will set up input and output devices but may appear hesitant and lack confidence at times. For one of the inputs, the planned requirements may not be met, for example they may locate a position sensor incorrectly, or use a sensor with a different input range than specified. They may sometimes require support from the Assessor to ensure that equipment is functioning as planned.
- Download data from the data logger and load this into a suitable computer system to interpret.
- Interpret and present some of the results of the data logging activity using basic graphical methods, such as a line graph, and tabular formats. They may not always use the most appropriate scales or range, however the data will be presented so that a third party could draw some conclusions from it.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 25: Computer Numerical Control Programming and Machining
- Unit 26: Robotics.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into how data logging is used in industry, for example for condition monitoring of machinery and the way in which the collected data is used
- providing scenarios for practical investigations to be based around
- work experience, which will allow learners to become familiar with the use of data logging and analysis within an engineering environment.


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## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate data logger, input and output devices to complete a data logging exercise.

### Managing information

- Interpreting and presenting data that has been collected using a data logger.

### Self-management and development

- Development of practical skills relating to completing investigations will be self-managed by learners.

# Unit 20: Electrical and Mechanical Science for Engineering

Level: **2**

Unit type: **Internal**

Guided learning hours: **30**

## Unit in brief

Learners will apply electrical and mechanical science principles to solve electrical and mechanical engineering problems.

## Unit introduction

Have you ever wondered why most new cars are advertised with warranties that are up to seven years long? Why are they so reliable and what makes them work so well?

Think about the latest hybrid cars that use a petrol engine and an electric motor. The technology in the car selects the best power source and controls the electrical and mechanical systems for the driver.

Electronically operated valves regulate the fuel and air into the engine; and for the electric system a multi-speed, multi-directional motor provides the electrical drive to the wheels. All cars have a suspension system; some of these can be adjusted at the press of a switch to match the road surface.

A car is made from components designed by electrical and mechanical engineers.

Think about what happens when a new car comes off the assembly line; it will be put through a number of electrical and mechanical tests to see if it is safe and working as it should. The engineers who designed the car and the technicians who will test it must understand the principles of electrical and mechanical science. A principle is a law or rule that sets out how things work – for example Ohm's law, which we use when calculating the current flowing in a circuit. Having done the calculation, we could set up the circuit using components and measure the current with a meter. Do the values correspond; if not, why not?

This unit is the starting point for you to learn how to solve problems in electrical and mechanical science using graphics and numbers.

You start by looking at electrical science: basic parameters such as voltage, current, power, magnetic field and magnetic flux. This then leads into electrical and magnetic circuits, the use of symbols to represent components, and ends with calculations – for example working out the current, power and force on a conductor. This is followed by the study of static mechanical systems, investigating how forces act on objects and developing an understanding of how to keep an object in equilibrium.

You will investigate dynamic mechanical science: linear motion and the calculation of speed, velocity, acceleration and the power needed to move an object in a straight line. The final topic is an introduction to fluids and pressure measurement – for example working out the pressure at the bottom of an oil tank or in a swimming pool.

## Learning aims

In this unit you will:

**A** Know engineering problems involving electrical science

**B** Know engineering problems involving mechanical science.

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## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Know engineering problems involving electrical science | **A1** Direct current circuits<br>**A2** Electromagnetic circuits | Preparation of a report that contains solutions to a number of tasks. Written, diagrammatic and numerical evidence. Evidence could be produced under supervision and individual values could be given for numerical tasks.<br>Practical evidence could be used – construction of circuits with measurement of parameters for example. |
| **B** Know engineering problems involving mechanical science | **B1** Statics<br>**B2** Representing static engineering systems<br>**B3** Dynamics<br>**B4** Fluids | Preparation of a report that contains solutions to a number of tasks. Written, diagrammatic, graphical and numerical evidence. Evidence could be produced under supervision and individual values could be given for numerical tasks.<br>Practical evidence could include experimental tasks to solve force systems by applying the parallelogram of forces. |

# Content

## Learning aim A: Know engineering problems involving electrical science

### A1 Direct current circuits

DC circuit parameters including:

- voltage, e.g. potential difference
- electro-motive force (emf)
- electrical charge
- current
- resistance
- power.

Component symbols and circuit diagrams:

- circuit symbols – battery, fixed value resistor, variable resistor, switch, ammeter, voltmeter, lamp, fuse, diode, light-emitting diode (LED)
- simple series and parallel circuit diagrams
- combined series and parallel circuit diagrams.

Use appropriate formulae to solve routine electrical circuit problems:

- calculate values of resistors in series $R_T = R_1+R_2+R_n$
- calculate values of resistors in parallel $1/R_T = 1/R_1+1/R_2 +1/R_n$
- Ohm's law $V=IR$
- calculate the current in a series circuit, current in a parallel circuit
- calculate the power in series and parallel circuits ($P=IV$, $P =I^2R$).

Use appropriate formulae to solve non-routine electrical circuit problems:

- calculate the power, current and potential differences in combined series/parallel circuits.

### A2 Electromagnetic circuits

Electromagnetic circuit parameters including:

- magnetic flux
- flux density.

Use appropriate formulae to solve routine electromagnetic circuit problems:

- interaction between a current-carrying conductor and magnetic field
- force on a current-carrying conductor ($F = BIL$).

Use appropriate formulae to solve non-routine electromagnetic circuit problems:

- torque produced by the armature of a simple DC motor ($T = nBILd$).

## Learning aim B: Know engineering problems involving mechanical science

### B1 Statics

Know the definitions and units for static systems:

- mass, weight, force ($w =mg$, $F =mg$)
- pressure ($P = F/A$)
- density, relative density
- moment of a force $M = F$ x $d$ (Nm)
- principle of moments

- static equilibrium of a body
- acceleration due to gravity ($g$ = 9.81ms$^{-2}$).

**B2 Representing static engineering systems**

Finding forces in routine engineering contexts using graphical methods, including:

- concurrent coplanar forces
- vector diagram to represent two forces
- parallelogram of forces
- triangle of forces
- resultant force
- equilibrant force.

Apply appropriate methods to solve routine engineering problems:

- simply supported beams with point loads
- a force acting on an object.

Use appropriate methods to solve non-routine engineering problems:

- the resultant and equilibrant of three forces acting on a point
- simply supported beams with point loads and a uniform distributed load.

**B3 Dynamics**

Know the definitions and units for dynamic systems:

- displacement
- the difference between speed and velocity
- acceleration/retardation
- the limiting coefficient of friction ($u = F/R$ )
- work done by a force acting on an object ($W = F$ x $d$)
- potential energy ($PE = mgh$)
- kinetic energy ($KE$ = ½ $mv^2$)
- power ($P = F$ x $d/t$ = work/time)

Use graphical techniques to represent dynamic systems:

- plot distance/time graphs
- plot displacement/time graphs
- plot velocity/time graphs.

Use appropriate methods to solve routine graphical representations:

- gradient to represent velocity
- gradient to represent acceleration/deceleration
- area under velocity time graph to represent distance travelled.

Use appropriate methods to solve non-routine graphical representations:

- maximum velocity
- time taken to accelerate or decelerate
- average velocity.

Investigate dynamic systems using equations of motion:

- $v = u + at$
- $v^2 = u^2 + 2as$
- $s = ut \, ½ + at^2$
- $s = ½ \, (u+v) \, t$.

Apply the appropriate formulae to solve routine engineering problems involving:

- motion
- work done
- energy
- power.

Apply the appropriate formulae to solve non-routine engineering problems involving:

- force acting on an object
- friction
- work done
- power.

**B4 Fluids**

Know the definitions and units for fluids and gases:

- atmospheric pressure
- gauge and absolute pressure
- density
- pressure at depth in a fluid
- pressure measurement using a U-tube manometer.

Apply the appropriate formulae to solve routine engineering problems involving:

- the density of a solid material
- the pressure at a depth in a fluid.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Know engineering problems involving electrical science** | | |
| **A.P1** Solve routine electrical science problems by applying appropriate methods. | **A.M1** Solve routine electrical science problems accurately and non-routine problems by applying appropriate methods. | **A.D1** Solve routine and non-routine electrical science problems accurately. |
| **Learning aim B: Know engineering problems involving mechanical science** | | |
| **B.P2** Solve routine and non-routine mechanical science problems accurately. | **B.M2** Solve routine mechanical science problems accurately and non-routine problems by applying appropriate methods. | **B.D2** Solve routine and non-routine mechanical science problems accurately. |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2 B.M2, B.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- science software packages suitable for Level 2 programmes, including:
  - electrical circuit simulation
  - electro-magnetism simulation
  - forces simulation
  - movement simulation
  - fluids simulation.

## Essential information for assessment decisions

### Learning aim A

**For Distinction standard**, learners will:

- Produce evidence that demonstrates that they can consistently apply routine and non-routine electrical science theory related to DC circuits and electromagnetic circuits to find accurate answers to problems.
- Show clear and logical steps when producing solutions to problems that may include minimal errors from transposition techniques or previous rounding of values carried through the working to the solution.
- Provide answers to an appropriate level of accuracy, showing the correct unit for these.

**For Merit standard**, learners will:

- Produce evidence that demonstrates that they can consistently apply routine electrical science theory related to DC circuits and electromagnetic circuits to find accurate answers to problems.
- Use appropriate methods for non-routine electrical science theory related to DC circuits and electromagnetic circuits to find answers to problems; however, there may be parts of the working that are incorrect.
- Show clear steps when producing solutions to problems that may include some errors from transposition techniques or previous rounding of values carried through the working to the solution.
- Provide answers to an appropriate level of accuracy, although there may be some mathematic errors and the unit might not always be correct for these.

**For Pass standard**, learners will:

- Produce evidence that demonstrates that they can apply routine electrical science theory related to DC circuits and electromagnetic circuits to find acceptable answers for problems.
- Show mostly suitable steps in the working using routine methods. Some errors may be evident that have been carried through from earlier working.
- Provide answers that are generally accurate but may not be in the correct format and units may not always be given.

## Learning aim B

**For Distinction standard**, learners will:

- Produce evidence that demonstrates that they can consistently apply routine and non-routine mechanical science theory to static, dynamic and fluid systems and produce accurate answers to problems.
- Show clear and logical steps when producing solutions to problems that may include minimal errors from transposition techniques or previous rounding of values carried through the working to the solution.
- Provide answers to an appropriate level of accuracy, showing the correct unit for these.

**For Merit standard**, learners will:

- Produce evidence that demonstrates that they can consistently apply routine mechanical science theory related to theory to static, dynamic and fluid systems to find accurate answers to problems
- Use appropriate methods for non-routine mechanical science theory related to static, dynamic and fluid systems to find answers to problems; however, there may be parts of the working that are incorrect.
- Show clear steps when producing solutions to problems that may include some errors from transposition techniques or previous rounding of values carried through the working to the solution.
- Provide answers to an appropriate level of accuracy, although there may be some mathematic errors and the unit might not always be correct for these.

**For Pass standard**, learners will:

- Produce evidence that demonstrates that they can apply routine mechanical science theory related to static, dynamic and fluid systems to find acceptable answers for problems.
- Show mostly suitable steps in the working using routine methods. Some errors may be evident that have been carried through from earlier working.
- Provide answers that are generally accurate but may not be in the correct format and units may not always be given.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 5: Mathematics for Engineering Technicians
- Unit 10: Engineering Fitting and Assembly
- Unit 13: Operations and Maintenance of Mechanical Systems and Components
- Unit 16: Application of Quality Control and Measurement in Engineering
- Unit 21: Renewable Technologies and Sustainability.

# Unit 21: Renewable Technologies and Sustainability

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

In this unit learners will examine methods of generating electricity from renewable sources, life cycle assessments and the use of lean manufacturing in engineering.

## Unit introduction

Have you ever wondered where electricity will come from in the future as reserves of coal, oil and gas become harder and more expensive to extract? The need to find and use alternative methods of producing electricity is something that has been the focus of engineers for many years, and now with an increasing demand for electricity for home use and for transport, these alternative approaches are becoming more important.

In this unit you will investigate how electricity can be generated from renewable sources including solar and wind power as well as ways in which energy can be stored.

You will then move on to look at the life cycle of an engineering product, thinking about the stages of a life cycle assessment. Links with renewable technologies can be made for the materials that are being used, for example can a material be used that has less demand for energy during extraction and processing, or can it be reclaimed or recycled at the end of use. You will demonstrate your understanding of the process by carrying out a life cycle assessment on a product such as a television, motorcycle or mobile phone.

Finally, you will look at ways in which waste can be reduced in engineering, not just in the production of engineered products but also during their use and disposal. This will include looking at lean manufacturing and ways to address the seven wastes of lean manufacturing such as using just in time or Kaizen for the manufacture of a product such as a car.

The unit can be applied within a specific area such as manufacturing, automotive or electronic engineering, but it is more likely that a range of sectors will be covered in the various assessment activities.

## Learning aims

In this unit you will:

**A** Explore the generation and storage of electricity from renewable energy sources

**B** Investigate the use of life cycle assessments for engineered products or services

**C** Investigate ways to reduce waste and improve sustainability of engineered products.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Explore the generation and storage of electricity from renewable energy sources | **A1** Generation of electricity from water<br>**A2** Generation of electricity from the wind<br>**A3** Generation of electricity from the sun<br>**A4** Energy storage | A report with annotated images/diagrams detailing the generation and storage of renewable energy. |
| **B** Investigate the use of life cycle assessments for engineered products or services | **B1** Stages of a life cycle assessment<br>**B2** Life cycle assessment report | A life cycle assessment report with annotated images/diagrams detailing the stages of the life cycle for a given engineering product. |
| **C** Investigate ways to reduce waste and improve sustainability of engineered products | **C1** Minimising waste during a product's lifecycle<br>**C2** Minimising waste using lean manufacturing methods<br>**C3** Engineering design for sustainability | A report with annotated images/diagrams detailing approaches to reduce waste during the production and use of engineering products. |

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# Content

## Learning aim A: Explore the generation and storage of electricity from renewable energy sources

### A1 Generation of electricity from water

How electricity is generated from water, the benefits and drawbacks of the technology and how they contribute to sustainability both locally and nationally.

Technology for generating electricity from water.

- Types of water-power installations:
  - hydro-electric: micro HEP, hydroelectric power stations
  - tidal systems
  - wave power.
- Components of a hydro-electric system:
  - mechanical components: surge tank, pressure tunnel, penstock, draft tube, inlet valve
  - electrical components: turbine, generator, transformer.
- Components of tidal systems:
  - mechanical components: caissons, sluice gates, turbine tunnel, vertical axis turbine blades, horizontal axis turbine blades,
  - electrical components: turbine, generator.
- Components of wave power systems:
  - mechanical components: point absorber buoy, surface/wave attenuator, terminators, hydraulic pumps
  - electrical components: linear generator, turbine.
- Function and operation of hydro-electric, tidal and wave power systems.
- Design factors for renewable energy generation from water: location, demand, local climate.

### A2 Generation of electricity from the wind

How electricity is generated from the wind, the benefits and drawbacks of the technology and how they contribute to sustainability both locally and nationally.

Technology for generating electricity from the wind.

- Types of wind turbine installation:
  - small scale wind turbine: horizontal axis, vertical axis
  - wind farms: onshore, offshore
  - wind pumps and micro-wind pumps.
- Components of a wind turbine.
- Structural components: tower, blades, nacelle:
  - control components: wind vane, anemometer, yaw drive and motor, pitch system, brake
  - generation components: low speed shaft, gearbox, high speed shaft, generator.
- Function and operation of wind turbines.
- Design factors for renewable energy generation from the wind: location, demand, local climate.

### A3 Generation of electricity from the sun

How electricity is generated from the sun, the benefits and drawbacks of the technology and how they contribute to sustainability both locally and nationally.

Technology for generating electricity from the sun.

- Types of solar photovoltaic installation:
  - roof mounted: on-roof, building integrated
  - free-standing
  - solar tracker: single-axis, dual-axis.
- Components of a solar photovoltaic system:
  - types of solar panel: monocrystalline, polycrystalline, concentrated PV cell
  - DC components: inverter, blocking diodes, isolator, fuses, generation meter
  - AC components: isolator, distribution board.
- Function and operation of solar photovoltaic systems:
  - design of solar photovoltaic systems: location, demand, local climate.
- Design factors for renewable energy generation from the sun: location, demand, local climate.

### A4 Energy storage

How energy from renewable sources can be stored, the reasons for storage of energy and their contribution to sustainability.

- Electricity storage methods, including:
  - electrical batteries, including utility stationary batteries, behind-the-meter (BTM) batteries
  - flow batteries
  - supercapacitors.
- Mechanical storage methods, including:
  - pumped hydro storage
  - flywheels.

## Learning aim B: Investigate the use of life cycle assessments for engineered products or services

### B1 Stages of a life cycle assessment

Characteristics, applications and advantages/disadvantages of Life Cycle Assessment (LCA) at the following stages for engineered products:

- raw materials extraction
- material production
- production of parts
- assembly
- distribution
- use
- repair and maintenance
- disposal/recycling.

### B2 Life cycle assessment report

Structure of a life cycle analysis report.

- Define the goal and scope of the assessment:
  - what is being assessed?
  - how will the assessment be completed?
  - define the limits of the assessment.
- Inventory analysis:
  - inputs: raw materials, energy, processes
  - outputs: products, emissions, waste.
- Impact assessment:
  - impact categories
  - measurement of impacts.
- Interpretation of results:
  - drawing conclusions
  - identifying limitations of the analysis
  - making recommendations.

## Learning aim C: Investigate ways to reduce waste and improve sustainability of engineered products

### C1 Minimising waste during a product's lifecycle

Characteristics, applications and advantages/disadvantages of minimising waste production throughout the life cycle of engineered products, using the four Rs:

- Reduce materials and energy.
- Reuse materials and products where applicable.
- Recover energy from waste.
- Recycle materials and products or use recycled materials.

### C2 Minimising waste using lean manufacturing methods

Characteristics, applications and advantages/disadvantages of minimising waste at the production stage in engineering, using lean manufacturing techniques.

- The 7 wastes of lean manufacturing:
  - transport
  - inventory
  - motion
  - waiting
  - over-processing
  - overproduction
  - defects
- Lean manufacturing techniques:
  - just-in-time (JIT)
  - Kaizen
  - poka-yoke.

**C3 Engineering design for sustainability**

Characteristics, applications and advantages/disadvantages of ways to improve the sustainability of engineering products during their life cycle.

- Design for manufacture, maintainability/serviceability, and reliability/longevity.
- Design for disassembly, remanufacture, repurposing or recycling.
- Design to minimise use of energy: during manufacture, use, maintenance and disposal.

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## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Explore the generation and storage of electricity from renewable energy sources** | | **A.D1** Describe in detail and accurately how a suitable renewable energy technology and a storage method would work for a given scenario to generate electricity, by comparing alternatives. |
| **A.P1** Select an adequate renewable energy source and a storage method for a given scenario to generate electricity.<br>**A.P2** Outline how the chosen renewable energy technology and the storage method would work for a given scenario to generate electricity. | **A.M1** Describe how a suitable renewable energy technology and a storage method would work for a given scenario to generate electricity, including the benefits to be gained. | |
| **Learning aim B: Investigate the use of life cycle assessments for engineered products or services** | | **B.D2** Assess detailed life cycle of a given engineered product or service, justifying outcomes. |
| **B.P3** Assess life cycle of a given engineered product or service adequately. | **B.M2** Assess life cycle of a given engineered product or service appropriately | |
| **Learning aim C: Investigate ways to reduce waste and improve sustainability of engineered products** | | **C.D3** Evaluate approaches to reduce waste and improve sustainability of engineered products throughout the lifecycle. |
| **C.P4** Describe how the use of the 4 Rs and lean manufacturing can reduce waste in engineering.<br>**C.P5** Describe adequately how product design can improve sustainability. | **C.M3** Explain approaches to reduce waste and improve sustainability of engineered products at most stages of the lifecycle. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.M2, B.D2)

Learning aim: C (C.P4, C.P5, C.M3, C.D3)

# Further information for teachers and assessors

## Resource requirements

There are no special resources needed for this unit.

## Essential information for assessment decisions

### Learning aim A

**For Distinction standard**, learners will:

- Describe in detail an appropriate renewable energy technology for the given situation. The description will consider the advantages and disadvantages of the renewable energy technology for the given situation, with reference to the components of the systems and how they operate, for example considering the number of solar panels that might be needed to supply electricity to an office building.
- Describe alternative methods of generating electricity and provide reasons why these alternative methods would not provide the best solution for the scenario.
- Include a detailed and accurate description of one method of storing electricity that is fully appropriate for the scenario, for example selecting and describing why a bank of batteries might be suitable for an off-grid wind turbine installation. The description will be technically correct, and the storage method will be appropriate for the renewable energy technology selected.

**For Merit standard**, learners will:

- Describe a suitable renewable energy technology for the given scenario, for example a solar photovoltaic system for a residential building. Learners will describe the purpose of most of the components in the system and how they work together to generate electricity, however there might be some minor omissions such as omitting the bypass diodes for a photovoltaic installation.
- Describe the benefits of electricity generated from the selected renewable source, for example describing how solar photovoltaic panels can be attached to an existing building structure.
- Describe one method that is suitable for storing electricity from the identified renewable energy technology, for example the use of battery packs to provide store power from a solar photovoltaic system.

**For Pass standard**, learners will:

- Select an adequate renewable energy source and a storage method for a given scenario to generate electricity. The renewable energy solution might not be the most appropriate, such as selecting a micro wind turbine as a power source for an office building. However, the selected storage method will be appropriate for the selected renewable energy technology.
- Describe briefly (in outline) how electricity is generated using a renewable energy technology that is adequate for the situation. The brief description should cover the components of the selected renewable energy technology and they may annotate a diagram of the system with a description of some of the components. There might be some omissions, but the brief descriptions will be mostly accurate.
- Also, describe briefly (in outline) one appropriate way that electricity from the selected renewable energy source can be stored, for example outlining the use of pumped storage for hydroelectricity.

### Learning aim B

**For Distinction standard**, learners will:

- Perform an appropriate, detailed and justified life cycle assessment for the engineered product that includes:
  - a justified goal and scope. Reasons will be given for what is being assessed, the way in which the assessment will be completed and the limits for the assessment. For example, only considering the stages from production of materials through to use for an engineered product that has a very long design life.
  - an assessment of all the stages before, during and after the manufacture of the given engineered product. The assessment will include the stages defined in the plan and draw on a range of sources of information and research to provide an appropriate and detailed analysis for each stage.

**For Merit standard**, learners will:

- Perform an appropriate life cycle assessment for the engineered product that includes:
  - a goal and scope that will allow the learner to draw conclusions and make recommendations to reduce the life cycle impact of the given engineered product.
  - an assessment of all stages before, during and after the manufacture of the given engineered product. There might be some omissions with regards to the inventory analysis, however these will be minor, for example emissions caused during the disposal of the product at the end of its life.

**For Pass standard**, learners will:

- Perform an adequate life cycle assessment for the engineered product that includes:
  - the goal and scope for assessment of a given engineering product. Some of the goals might not be the most suitable, however they will still allow the learner to investigate the product and produce an adequate report.
  - at least one input and one output that is associated with the manufacture of the product, for example the raw materials used during manufacture and the waste produced.

### Learning aim C

The assessment for this learning aim must allow learners to carry out an investigation into ways that waste can be reduced during the lifecycle of engineering products. Products should allow for the whole life cycle to be investigated, for example a motor vehicle, household appliance or electronic devices such as a laptop computer or mobile phone/cell phone. Learners may refer to one or more product, however there should be opportunity to consider the 4 Rs, lean manufacturing and also design for sustainability.

**For Distinction standard**, learners will:

- Evaluate the advantages and disadvantages of using the 4 Rs to reduce waste in engineering. The evaluation will use technical language with accuracy and will be balanced, for example comparing the advantages of environmental benefits of reusing materials against the disadvantages of the costs involved.
- Include advantages and disadvantages of using just-in-time, Kaizen and poka-yoke to minimize the seven wastes of lean manufacturing. The lean manufacturing approaches will be appropriate to reduce the specific type of waste identified, for example the benefits of just-in-time to reduce inventory waste.

- Evaluate the advantages and disadvantages of the ways that designers of engineered products can reduce waste. For example, comparing the benefits of design for disassembly with the more complex processes that might be needed to manufacture the product.

**For Merit standard**, learners will:

- Explain of how the 4 Rs can be used to reduce waste in engineering. The explanations will make links between the approach and use technical language appropriately. For example, they might make the connection between recycling aluminium off-cuts and the reduced need for new raw materials to be produced.
- Explain the types of waste that are associated with lean manufacturing. They will consider most of the seven wastes, although they could contain some minor errors for example when writing about over processing and over production.
- Explain the ways in which designers of engineered products can reduce waste, for example making connections between designing for minimal use of energy during use and how this improves the sustainability of the product over most of its life span.

**For Pass standard**, learners will:

- Describe adequately:
  - the 4 Rs and how they contribute to reducing waste in engineering. The descriptions might be limited, but they will be technically accurate and identify the differences between each approach.
  - at least four of the different types of waste that are associated with lean manufacturing. There might be some omissions or inaccuracies in the descriptions, however the descriptions will be within an appropriate engineering context.
- Describe adequately the ways in which designers of engineered products can improve the sustainability of products during some stages of the product lifecycle. For example, by designing for recycling or by using fewer types of materials to manufacture a product.

## Links to other units and curriculum subjects

This unit links to most other units.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, to share insights into the use of renewable sources of energy for generating electricity, the locations in which they are used and the reasons why they might be used locally
- case studies for engineered products to be used for life cycle assessments
- site visits to engineering organisations who have adopted lean manufacturing techniques
- design challenges related to reducing waste
- work experience, which will allow learners to become familiar with concepts covered across the three learning aims.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate approaches and solutions for engineering problems.

### Managing information

- Collecting and interpreting information to produce reports.

### Self-management and development

- Development of analytical skills relating to the completion of a life cycle assessment for a given engineering product.



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# Unit 22: Electrical and Electronic Circuit Construction and Testing

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners wil carry out circuit calculations and safely build electrical and electronic circuits. They will carry out measurements and fault find on pre-constructed circuits.

## Unit introduction

Have you ever wondered how products like amplifiers, power supplies and computers are constructed? In reality, they are all made using similar practical techniques and skills.

In this unit, you will investigate, build and test circuits so you understand how they work.

You will learn how to work safely by applying safe working practices in relation to electrical and electronic circuits. You will identify electrical hazards and eliminate any risks.

You will develop your understanding of how circuits work in theory and practice. You will investigate different types of electrical and electronic components. You will learn how to select commonly used components. This will include carrying out circuit related calculations.

You will use standard circuit symbols in circuit diagrams to select components and you will build electrical and electronic circuits safely, using a range of construction techniques.

You will use equipment such as multimeters, oscilloscopes and signal generators to test an electrical or electronic circuit. You will have also have the opportunity to find and fix faults in circuits.

## Learning aims

In this unit you will:

**A** Understand key electrical, electronic and circuit operating principles using safe working practices

**B** Use components to safely construct electrical and electronic circuits

**C** Carry out measurements and tests to find faults on an electrical or electronic circuit.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Understand key electrical, electronic and circuit operating principles using safe working practices | **A1** Safe working practices<br>**A2** Electrical and electronic principles<br>**A3** Circuits | A poster/booklet describing how to apply safe working practices when constructing electrical and electronic circuits.<br>A written exercise devised to confirm understanding of electrical/electronic principles.<br>A report detailing the function, operation and applications of series and parallel circuits, and an electronic circuit, e.g. an amplifier or a power supply that includes rectification and smoothing. |
| **B** Use components to safely construct electrical and electronic circuits | **B1** Components<br>**B2** Circuit construction<br>**B3** Circuit operation | A short report for each circuit constructed. Each report should include a circuit diagram, a component list, a description of the safe working practices followed, accuracy checks and annotated photographs of the constructed circuit. |
| **C** Carry out measurements and tests to find faults on an electrical or electronic circuit | **C1** Measurement and testing<br>**C2** Fault-finding techniques | A fault-finding report card that identifies: the circuit under test, initial observations, test plan, sequence of tests carried out with justification, outcomes and conclusions, identification of fault, annotated photographs. |

# Content

## Learning aim A: Understand key electrical, electronic and circuit operating principles using safe working practices

### A1 Safe working practices

Safe working practices in relation to electrical and electronic systems:

- identifying hazards, e.g. sharp-edged hand tools, soldering irons, toxic substances
- reporting issues
- safe use of electrical equipment – inspection, testing and replacement of equipment, e.g. cables and connectors, mains connectors and fuses, portable appliances, compliance with legislation
- prevention of electric shock – the need for isolation, fault protection devices, e.g. residual circuit breakers (RCD), earth leakage circuit breakers (ELCB)
- effective grounding and earthing of non-insulated equipment, e.g. metal enclosures, exposed metal chassis.

### A2 Electrical and electronic principles

Application of electrical and electronic principles:

- electrical units and the relationship between them, e.g. charge, current (supply and branch currents), voltage (potential difference), resistance, power and fuse rating in direct current (DC) circuits
- series, parallel and mixed circuits, e.g. calculate total resistance, current, power dissipation and potential difference in direct current (DC) circuits
- single phase alternating current supply parameters e.g. determine frequency, time period, amplitude (peak voltage), peak-to-peak voltage, root mean square value (rms).

### A3 Circuits

Circuit diagrams:

- graphical symbols for use in electrotechnical diagrams, e.g. IEC 60617 (BS3939), IEEE 315 or international equivalent.

The function, operating principles, effect of component values and typical applications of circuits:

- series, parallel and mixed series/parallel resistor circuits e.g. current and potential difference measurements, total resistance
- an electronic circuit, e.g.:
    - amplifier, for example an inverting operational amplifier of given voltage gain (input and output voltage signals, component values
    - a DC power supply including rectification and smoothing, for example RMS input voltage, relationship between alternating and rectified waveforms, ripple voltage, the effect of load resistor on the ripple voltage.

## Learning aim B: Use components to safely construct electrical and electronic circuits

### B1 Components

Range of components, to include:

- cells and batteries, loudspeakers and buzzers, connectors, capacitors, variable and pre-set capacitors, resistors, variable resistors, pre-sets and potentiometers, transformers, inductors and pre-set inductors, diodes, transistors, integrated circuits, switches.

Selection of electrical and electronic components:

- by calculation (resistance, voltage, current, power rating)
- from circuit diagram
- visually – component type, outline, physical encapsulation, size, shape
- using colour codes – value, tolerance, voltage rating.

### B2 Circuit construction

Select appropriate methods to construct electrical circuits and an electronic circuit safely, e.g. series, parallel and mixed resistor circuits, an electronic circuit such as a power supply or an amplifier circuit:

- construction methods, e.g. bread-board, matrix board, Veroboard, printed circuit board (PCB), soldering, other interconnection methods such as plug-in prototype systems.

Safe use, for the correct purpose only, of:

- personal protective equipment, e.g. safety glasses
- hand tools, e.g. screwdriver, pliers, cutters, knives
- soldering equipment, e.g. soldering iron, solder, soldering and desoldering tools, ventilation system
- PCB manufacturing tools, e.g. etching equipment, PCB drills.

### B3 Circuit operation

Checking the constructed circuit:

- visual inspection, e.g. comparison with circuit diagram, correct component values e.g. using colour code; components correctly positioned and oriented e.g. diodes, electrolytic capacitors
- simple operational checks, e.g. test point voltages, waveform characteristics, gain.

## Learning aim C: Carry out measurements and tests to find faults on an electrical or electronic circuit

### C1 Measurement and testing

Measurement and testing techniques to determine circuit parameters for an electrical or electronic circuit:

- measuring instruments and test equipment, e.g. power supply, multimeter, signal generator, oscilloscope, insulated test leads and probes
- circuit parameters, e.g. voltage, current, resistance, voltage gain, frequency, period.

**C2 Fault-finding techniques**

Using fault-finding techniques on a pre-constructed electrical or electronic circuit:

- test point voltage and current measurement, e.g. DC values, RMS values, magnitude form and frequency of alternating waveforms
- typical simple faults, short circuit (e.g. bridged tracks), open circuit (e.g. broken track, dry solder joint), incorrect or damaged component
- signal tracing, e.g. input to output, output to input, half split method
- use of fault-finding aids, e.g. functional charts, diagrams, trouble-shooting charts, component data sheets
- record keeping of measurements and conclusions, e.g. fault-finding report form.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Understand key electrical, electronic and circuit operating principles using safe working practices</td><td rowspan="4">AB.D1 Evaluate how different circuit values affect their operation and application.</td></tr>
<tr><td>A.P1 Describe safe working practices when building circuits.<br>A.P2 Describe the operation of an electronic circuit.<br>A.P3 Determine voltage, current, resistance, power, supply current and fuse ratings in series, parallel and mixed resistor circuits.</td><td>A.M1 Explain the operation and typical applications of an electronic circuit.<br>A.M2 Explain the impact of different circuit values in series, parallel and mixed resistor circuits.</td></tr>
<tr><td colspan="2">Learning aim B: Use components to safely construct electrical and electronic circuits</td></tr>
<tr><td>B.P4 Select appropriate components to safely build an electrical circuit and an electronic circuit.<br>B.P5 Use suitable construction methods to safely build an electrical circuit and an electronic circuit.</td><td>B.M3 Safely and accurately build an electrical circuit and an electronic circuit.</td></tr>
<tr><td colspan="2">Learning aim C: Carry out measurements and tests to find faults on an electrical or electronic circuit</td><td rowspan="2">C.D2 Evaluate the effectiveness of the fault-finding techniques used to identify simple faults in a pre-constructed circuit.</td></tr>
<tr><td>C.P6 Measure, test and record circuit parameters for a pre-constructed circuit.</td><td>C.M4 Use signal tracing, test point voltage and current measurement to identify simple faults in a pre-constructed circuit.</td></tr>
</table>

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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, A.P3, B.P4, B.P5, A.M1, A.M2, B.M3, AB.D1)

Learning aim: C (C.P6, C.M4, C.D2)

Learner evidence can be a combination of learner-generated supporting evidence and an observation record. Diagrams and images can be taken from reference sources but they must be supported by the learner's 'own writing' and referenced appropriately.

Plug-in or breadboard style prototype systems are suitable for connecting the resistor combination circuits. The electronic circuit should use a more permanent construction method that requires soldering skills.

The electronic circuit examples for learning aims A and B are given as a guide to circuit complexity and are not prescriptive. The focus is on the construction and testing of circuits. Learners should be supplied with circuit diagrams and layouts. They may be given layout diagrams for alternative construction methods for a circuit, e.g. Veroboard or PCB, to select the most appropriate. They do not have to design their own layouts.

The pre-constructed circuits for fault-finding exercises for learning aim C are not prescribed as centres will have different resources and local specialisations. It is advised to construct the circuits on printed circuit board with accessible test points and in-built switched faults such as short circuit (e.g. bridged tracks), open circuit (e.g. broken track, dry solder joint), incorrect or damaged component. They need to be complex enough for learners to meet all the assessment criteria, for example a light or temperature operated alarm or a class A transistor amplifier. Learners should apply only one fault at any time.

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to

- a fully equipped electronics laboratory
- electrical or electronic circuit construction equipment
- test equipment, including oscilloscopes, signal generators, pulse generators, low voltage power supplies and multimeters pre-constructed circuits for fault finding exercises (see *Essential information for assignments*).

## Essential information for assessment decisions

For learning aims A and B learners need to provide assessment evidence related to electrical circuits and an electronic circuit. The electronic circuit must be consistent throughout the assessment.

## Learning aims A and B

**For Distinction standard**, learners will:

- Demonstrate a thorough understanding of safe working practices when working with electrical and electronic circuits.
- Accurately solve realistic and contextualised problems relating electrical parameters in series, parallel and mixed resistor circuits with consistent use of correct units.
- Provide an in-depth evaluation of the safe construction, operation and typical applications of series, parallel and mixed resistor circuits and an electronic circuit such as an amplifier circuit (e.g. inverting operational amplifier of given gain) or a DC power supply incorporating rectification and smoothing.

  The evaluation should include circuit diagrams, justification of the construction methods used, construction accuracy checks, comparison with the expected circuit operation and annotated photographs. Overall, the evidence will be structured logically and use correct technical engineering terms. Construction will be carried out safely to a very good standard.

**For Merit standard**, learners will:

- Demonstrate a good understanding of safe working practices when working with electrical and electronic circuits.
- Solve realistic and contextualised problems relating electrical parameters in series, parallel and mixed resistor circuits. The solutions should be mainly accurate but there may be minor errors or occasional omissions, e.g. some units.
- Explain the safe construction and operation of series, parallel and mixed resistor circuits and an electronic circuit, for example an amplifier circuit (e.g. inverting operational amplifier of given gain) or a DC power supply incorporating rectification and smoothing.
- The explanations should include a circuit diagram, an explanation of the safe construction methods used, accurate measurements and annotated photographs. The explanations should be mostly complete, e.g. minor detail may be omitted, and there may be a few technical inaccuracies. Construction will be carried out safely to a good standard.

**For Pass standard**, learners will:

- Solve realistic and contextualised problems using basic electrical and electronic principles, e.g. calculate the total resistance, currents and voltages for two or more resistors connected in series and parallel and four or more resistors in series/parallel combination. There may be some errors and omissions.
- Describe the safe construction and operation of series, parallel and mixed resistor circuits. Learners will describe how they measured current and voltage and record their results.
- Describe the safe construction and operation of an electronic circuit, e.g. an amplifier circuit such as an inverting operational amplifier of given gain, or a DC power supply incorporating rectification and smoothing. They must select appropriate components to use for the electronic circuit constructed. They will describe how they measured current and voltage and record their results. Learners need to demonstrate the safe use of circuit manufacturing equipment within the workshop. The electronic circuit must be the one constructed.
- The description should include a circuit diagram, a description of the safe construction methods used, and annotated photographs. The description may be basic in parts, e.g. some detail may be omitted, and it may contain minor technical inaccuracies, e.g. relating to engineering terminology. Construction will be carried out safely to a reasonable standard.

## Learning aim C

For learning aim C learners need to provide assessment evidence related to an electrical or an electronic circuit. It is not necessary or appropriate for learners to cover both types for assessment. Examples of suitable circuits are given above in the *Essential information for assignments*.

**For Distinction standard**, learners will:

- Select and use appropriate methods and instruments to begin fault finding on a pre-constructed circuit based on initial observations.
- Carry out a sequence of measurements and tests to follow based on conclusions drawn from measurements.
- Identify at least two single faults in a circuit (i.e. only one fault must be switched in at any one time).
- Record test and measurement results accurately.
- Evaluate the effectiveness of the fault-finding methods used to identify the faults. The evaluation should justify the fault-finding methods used to efficiently identify at least two faults. Overall, the evidence will be structured logically and use correct technical engineering terms.

**For Merit standard**, learners will:

- Select and use appropriate methods and instruments to apply fault-finding techniques on a pre-constructed circuit.
- Record the test and measurement results using a fault-finding report form.
- Identify one common fault in a circuit, e.g. dry joint, broken track, open circuit or short circuit component.
- Explain the fault-finding process carried out to identify the fault. The explanation should be mostly complete and correct. Minor detail may be omitted, and there may be a few technical inaccuracies, e.g. misinterpreting a measurement outcome resulting in the need to carry out more tests to find a fault.

**For Pass standard**, learners will:

- Use at least two different measuring instruments correctly to measure circuit parameters on a pre-constructed circuit with switched faults, e.g. a light or temperature-controlled alarm, transistor amplifier.
- Record the test and measurement results on a standard template. Some detail may be omitted, and there may be minor inaccuracies, e.g. a unit may be written as V when it should be mV.
- Demonstrate compliance with safe working practices when taking measurements.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 5: Mathematics for Engineering Technicians
- Unit 20: Electrical and Mechanical Science for Engineering
- Unit 23: Electronic Devices and Communication Applications
- Unit 24: Operations and Maintenance of Electrical and Electronic Systems and Components.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate techniques and tooling to safely construct and test electrical and electronic circuits.

### Managing information

- Collecting, recording and interpreting data from various sources.

### Self-management and development

- Development of practical skills relating to circuit construction and fault-finding processes will be self-managed by learners.

# Unit 23: Electronic Devices and Communication Applications

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

This unit gives learners the opportunity to investigate signals, systems, components and devices used in electronic communication and data transmission and to build and test circuits so that they can understand how they work.

## Unit introduction

Electronic devices and communications methods have brought about a revolution in how we communicate. Computers, tablets, cellular phones, global positioning systems, activity trackers and games platforms have opened up previously unthought-of ways of transmitting and receiving data. Have you ever wondered how they work? They all perform their tasks because they link together electronic devices made up from thousands of electronic components. A mobile phone, for example, contains a 'system on a chip' (integrated circuit) that includes the processor core, graphics chip, cellular radio, mobile RAM, image processor and audio/video decoders.

You will learn the basics of signals and the units of measurement used in electronic communication and data transmission to give you the underpinning knowledge to carry out practical investigations. You will investigate commonly used electronic components and devices and build analogue and digital circuits. You will also test their operation using equipment such as multimeters and oscilloscopes to understand how they work.

## Learning aims

In this unit you will:

**A** Investigate signals and systems used in electronic communication and data transmission

**B** Investigate electronic components and devices and data transmission systems and their function

**C** Build and test analogue and digital electronic circuits safely.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate signals and systems used in electronic communication and data transmission | **A1** Signals and units<br>**A2** Digital data representation<br>**A3** Electronic communication systems | A report on the characteristics of analogue and digital signals. |
| **B** Investigate electronic components and devices and data transmission systems and their function | **B1** Components<br>**B2** Devices | A practical activity based on physical circuits and circuit diagrams. |
| **C** Build and test analogue and digital electronic circuits safely | **C1** Analogue circuits<br>**C2** Digital circuits<br>**C3** Construction and testing techniques | A log supported by an observational witness statement on the building and testing of analogue and digital circuits. |



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# Content

## Learning aim A: Investigate signals and systems used in electronic communication and data transmission

### A1 Signals and units

Types, application and measurement of various signals:

- analogue signals, the signal level can be any value within limits with time e.g. light intensity, temperature, speech waveforms , vinyl record
  - alternating waveforms, e.g. sinusoidal, triangular or sawtooth
  - waveform measurements, e.g. amplitude, peak to peak, cycle, periodic time, frequency, phase and speech waveforms.
- digital signals, signal level can only be one of a fixed number of discrete levels at a given time e.g. compact disc, mp4 file
  - digital waveforms e.g. square wave, pulse, coded
  - waveform measurements, e.g. amplitude, pulse duration, mark/space ratio, repetition rate, periodic time, frequency.

Units of measurement:

- standard SI units
  - voltage, current, frequency, transmission rate
  - standard prefixes for small or large measurements e.g. micro (μ), milli (m), kilo (k), mega (M), giga (G), tera (T).

### A2 Digital data representation

Characteristics of digital signals:

- digital logic levels, represented by high/low, 0/1
- binary number system e.g. convert whole numbers into binary numbers (0 to 9), convert binary numbers (up to 4 bits) to whole numbers (base 10), hexadecimal
- how characters can be represented in binary format e.g. Morse code, ASCII, BCD
- units used to describe memory and data storage (bit, byte, kilobyte, megabyte, gigabyte, terabyte, petabyte).

### A3 Electronic communication systems

Features, principles, applications and advantages of electronic communications systems.

- Block diagram of a typical system, e.g. cellular phone, local WiFi, Bluetooth:
  - transmitter sub systems, e.g. audio source, radio transmitter
  - transmission medium, e.g. radio waves, optical fibre, copper wire, microwaves
  - receiver, e.g. radio, television, computer.
- Protocols:
  - simplex, one-way communication only, e.g. television broadcast
  - half duplex, one-way communication at any one time, e.g. walkie-talkie radio
  - duplex, two-way communication at any time, e.g. cellular phone
  - control protocols, e.g. handshaking, flow control, error checking.
- Long distance communication, the need for repeaters/regenerators, e.g. internet, satellite communications.

## Learning aim B: Investigate electronic components and devices and data transmission systems and their function

### B1 Components

The functions, operating characteristics, applications, physical forms and graphical symbols (e.g. IEC 60617 (BS3939) IEEE 315 or international equivalent) of electronic components:

- cells, batteries, power supplies
- connectors
- resistors, variable resistors, pre-set resistors
- capacitors, variable capacitors, pre-set capacitors
- inductors/chokes, transformers
- diodes, e.g. signal, power, Zener
- transistors (bipolar and unipolar).

### B2 Devices

The functions, operating characteristics, physical forms, graphical symbols (e.g. IEC 60617 (BS3939) IEEE 315 or international equivalent) and applications of devices:

- switches, e.g. normally open (NO), normally closed (NC), change over (CO), single pole single throw (SPST), single pole double throw (SPDT), double pole double throw (DPDT), push button, rocker, toggle, rotary, microswitch, tilt, pressure
- transducers, e.g. light dependent resistor (LDR), photodiode, thermistor, thermocouple, microphone, strain gauge
- indicators and output devices, e.g. lamp, LED, 7-segment display, buzzer, speaker, relay, motor, solenoid, heater
- integrated circuits:
  - operational amplifiers, e.g. inverting and non-inverting amplifiers, comparator
  - timers and clocking circuits, e.g. monostable and astable.
- two input logic gates, e.g. AND, OR, NOT, NAND, NOR, XOR.

## Learning aim C: Build and test analogue and digital electronic circuits safely

### C1 Analogue circuits

Understanding the operation and function of analogue circuits using various construction techniques to construct circuits:

- passive circuits:
  - combinations of series and parallel resistors, e.g. resistors in series with 2 resistors in parallel
  - two capacitors in series and parallel combinations
  - charge and discharge of a capacitor, e.g. time constant T = CR, charge and energy storing.
- active circuits:
  - diode as a one-way device, e.g. use of diode for device protection, circuits comprising diode-resistor combinations, turn on voltage, Zener diode stabiliser
  - bipolar and unipolar transistor circuits, e.g. transistor operation as an amplifier and as a switch
  - linear integrated circuits e.g. operational amplifier acting as inverting or noninverting amplifier.

### C2 Digital circuits

Understanding the operation and function of digital circuits using various construction techniques to construct circuits, including:

- digital circuits:
  - 2-input logic gates truth tables e.g. using 74 Series or CMOS 4000B series integrated circuits
  - combinational logic circuits and truth tables, e.g. using 74 Series or CMOS 4000B series integrated circuits or teaching laboratory modules
  - timer and clock circuits e.g. 555 time in monostable and astable modes.

### C3 Construction and testing techniques

Using construction techniques to construct analogue and digital circuits:

- Construction techniques to include:
  - Protoboard e.g. breadboard
  - Veroboard
  - Printed circuit board (PCB).

Using measurement and testing techniques to determine circuit parameters for constructed circuits:

- measuring instruments and test equipment, e.g. power supply, multimeter, signal generator, oscilloscope, insulated test leads and probes, logic probe, and pulse generator
- test point voltage and current measurement e.g. dc values; magnitude, form, rms value, time period and frequency of alternating waveforms; logic levels, mark/space ratio.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate signals and systems used in electronic communication and data transmission** | | |
| **A.P1** Describe the characteristics of analogue and digital signals using appropriate units.<br>**A.P2** Describe how numbers and characters can be represented in binary.<br>**A.P3** Describe an electronic communication or data transmission system. | **A.M1** Explain the differences between analogue and digital signals and how they can represent data.<br>**A.M2** Explain the operation of an electronic communication or data transmission system. | **A.D1** Compare an electronic communication or data transmission system that uses analogue signals with a system that uses digital signals. |
| **Learning aim B: Investigate electronic components and devices and data transmission systems and their function** | | |
| **B.P4** Identify electronic components and devices in a physical circuit and from their symbols in a circuit diagram.<br>**B.P5** Describe the function of electronic components and devices. | **B.M3** Explain the function of each electronic component and device in a given circuit. | **B.D2** Analyse how a given circuit operates due to the function of each electronic component and device. |
| **Learning aim C: Build and test analogue and digital electronic circuits safely** | | |
| **C.P6** Safely build and test the operation of a passive analogue circuit.<br>**C.P7** Safely build and test the operation of an active analogue electronic circuit.<br>**C.P8** Safely build and test the operation of a digital electronic circuit. | **C.M4** Use different methods of construction to safely and accurately build and test the operation of a passive analogue circuit, an active analogue electronic circuit and a digital electronic circuit. | **C.D3** Use different methods of construction to safely and accurately build and test the operation of a passive analogue circuit, an active analogue electronic circuit and a digital electronic circuit showing forward thinking and initiative. |



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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.M2, A.D1)

Learning aim: B (B.P4, B.P5, B.M3, B.D2)

Learning aim: C (C.P6, C.P7, C.P8, C.M4, C.D3)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a fully equipped electronics laboratory
- test equipment, including oscilloscopes, signal generators, pulse generators, low voltage power supplies, logic probes and multimeters
- electronic circuit construction equipment
- a range of components and devices
- circuit diagrams and physical layout diagrams for circuits to be constructed
- reference material, e.g. online sources, catalogues, data sheets, component colour charts
- computer access for internet-based research.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Provide an evaluation of an electronic communications or data transmission system. The evaluation must consider the advantages and disadvantages of the systems used. Learners will demonstrate how data can be encoded for transmission. They will compare the appropriateness of simplex, half-duplex and duplex communication for their chosen system, and how signals, e.g. handshaking, are used to control data flow. Learners will also include how repeaters/regenerators allow data to be transmitted over longer distances.
- Use appropriate units consistently.

**For Merit standard**, learners will:

- Compare the characteristics of analogue and digital signals.
- Explain the functions of an electronic communications or data transmission system. The explanation should include an annotated block diagram, the function of the subsystems and typical waveforms at key points.
- Explain, with examples, how data is encoded for transmission.
- Use appropriate units on most occasions.

**For Pass standard**, learners will:

- Provide information on the characteristics of analogue and digital signals. They must include diagrams to illustrate their descriptions. Learners may describe a digital signal only as a binary logic syste.
- Convert numbers 0-9 into binary values and demonstrate how to convert a 4-bit binary value into decimal and hexadecimal.
- Identify coding systems for electronic transmission of characters, e.g. Morse, ASCII, audio tones.
- Provide information on electronic communications or data transmission systems. Learners should include a block diagram and description of the subsystems.

Diagrams may come from a researched source but must be accompanied by the learner's 'own writing' and be referenced.

## Learning aim B

**For Distinction standard**, learners will:

- Provide a detailed analysis of how a given circuit (e.g. a variable speed motor circuit) operates with accurate descriptions of the function of all electronic components and devices that make up the circuit.
- Show how the performance of an output device can be altered by using pre-set or variable electronic components and input logic gates.
- Produce well-presented circuit diagrams showing the correct use of all symbols for the components and devices. The evidence will be logical with the correct use of engineering terms throughout.

**For Merit standard**, learners will:

- Explain the function of the electronic components and devices in a given circuit (e.g. a variable speed motor circuit). The explanation will be generally accurate with the correct terminology used in most cases.
- Explain how the component, device or logic gate can change the output or features of the circuit; however this might use simple terms or be brief in content and detail.
- demonstrate the use of mostly correct standard symbols in circuit diagrams although there may be occasional technical inaccuracies in some of the terms used.

**For Pass standard**, learners will:

- Correctly identify some of the electronic components used in a given circuit (e.g. a variable speed motor circuit) and from a circuit diagram.
- Demonstrate an understanding of the function of electronic components and devices in a circuit. Some of the descriptions may be basic in parts and may lack detail. There could also be some technical inaccuracies relating to engineering terminology.
- Produce circuit diagrams that are not always accurate but should be clear and use basic but recognisable symbols that represent components and devices.

## Learning aim C

**For Distinction standard**, learners will:

- Show advance planning and initiative when considering safe, effective and efficient techniques and using different methods when constructing analogue and digital circuits.
- Demonstrate a thorough understanding of safe working practices for different methods of constructing circuits. Construction will be carried out to a very good standard and will be supported by an observation or witness record.
- Demonstrate the correct selection and use of tools, components and devices for the circuits. This should include the value of a component, e.g. the correct size of resistors for a circuit.
- Test the circuits to ensure the build is successful and provide an evaluation of the operation and a detailed description of typical applications of the constructed analogue and digital circuits. It would be expected that an accurate circuit diagram for each circuit is presented.

**For Merit standard**, learners will:

- Demonstrate a good understanding of safe working practices when working with electrical and electronic circuits.
- Demonstrate the correct selection and use of most tools, components and devices for the analogue and digital circuits. This should include the value of a component, although there may be some recognisable errors in the selection relating to, e.g. the size of a resistor. Construction will be carried out safely to a good standard and will be supported by an observation or witness record.
- Test the circuits to ensure the build is successful and explain, using correct terminology, the operation of each circuit. There should be some suggestions of a typical application for these although the descriptions for these might not be detailed.

**For Pass standard**, learners will:

- Provide information on safe working practices when building electrical and electronic circuits.
- Select and use a range of tools, components and devices for the circuits with some guidance on the appropriateness of these. Construction will be carried out safely to a reasonable standard and will be supported by an observation or witness record.
- Test the circuits to ensure the build is successful and provide a description, using basic terminology of how each circuit operates.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 20: Electrical and Mechanical Science for Engineering
- Unit 22: Electrical and Electronic Circuit Construction and Testing
- Unit 24: Operations and Maintenance of Electrical and Electronic Systems and Components.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into industrial techniques and the importance of electrical and electronic circuits and devices not only to a wide range of engineering sectors, but also to the general population
- availability of procedures used to ensure safety in manufacture, quality checks and the need to maintain accurate records
- documentation, such as a range of circuit drawings, electrical specifications and data sheets
- work experience, which will allow learners to become familiar with industrial manufacturing techniques and the typical industrial environments in which they are used. The nature of the knowledge and skills being developed in this unit mean that it is particularly suited to incorporating a period of work experience. Learners could, for example, shadow an operator constructing circuit boards or carrying out quality checks on completed circuits.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate techniques and equipment to safely build and test electrical and electronic circuits.

### Managing information

- Collecting, recording and interpreting data from various sources.

### Self-management and development

- Development of practical skills relating to circuit construction and testing processes will be self-managed by learners.

# Unit 24: Operation and Maintenance of Electrical and Electronic Systems and Components

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

This unit gives learners the opportunity to investigate electrical and electronic systems and their components so that they can safely carry out maintenance, fault finding and rectification exercises.

## Unit introduction

Have you ever thought about how important electrical and electronic systems are to our everyday lives? Modern manufacturing methods are highly dependent on electricity to power machines, lighting, heat and other services. Automated systems use robotics and Computer Numerically Controlled (CNC) machines to manufacture everything from small components to cars. The technology is also entering everyday lives through virtual assistants in ‘smart homes’. These devices control electrical systems using electronic systems.

An electrical and electronics maintenance engineer is responsible for the maintenance and repair of a wide variety of electrical and electronic engineering equipment. Some may specialise in industrial systems within a factory. Others may concentrate more on domestic systems within businesses and homes. Wherever they work they have to know about workplace hazards and health and safety requirements, such as personal protection, safe working practices and the safe handling of electrical and electronic equipment.

You will investigate electrical and electronic systems to be able to understand how they work. You will learn how to identify components and understand their function in the system. Knowing how a system works is vital when carrying out inspection and maintenance activities, identifying faults and rectifying them. You will prepare for and safely carry out a routine maintenance and a fault-finding and rectification activity on electrical and electronic systems.

## Learning aims

In this unit you will:

**A** Investigate the operation of electrical and electronic systems and the function and operation of components used in them

**B** Select components used in electrical and electronic systems during routine maintenance

**C** Prepare for and safely carry out routine maintenance on electrical or electronic systems

**D** Prepare for and safely carry out fault-finding and fault-rectification on electrical or electronic systems.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate the operation of electrical and electronic systems and the function and operation of components used in them | **A1** Electrical systems<br>**A2** Electronic systems<br>**A3** Electrical and electronic system components | A report based upon the electrical system and the electronic system investigated, with annotated images/diagrams/photographs can be included. |
| **B** Select components used in electrical and electronic systems during routine maintenance | **B1** Electrical and electronic system data<br>**B2** Component data<br>**B3** Component selection | A practical activity with maintenance report involving the safe preparation and carrying out of a maintenance task. |
| **C** Prepare for and safely carry out routine maintenance on electrical or electronic systems | **C1** Safety<br>**C2** Routine maintenance tasks | |
| **D** Prepare for and safely carry out fault-finding and fault-rectification on electrical or electronic systems | **D1** Identification of faults in an electrical or electronic system<br>**D2** Fault rectification | A practical activity and report involving the safe preparation and carrying out of a fault-finding and rectification task, to include a small portfolio with media and observation records/witness statements. |



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## Content

### Learning aim A: Investigate the operation of electrical and electronic systems and the function and operation of components used in them

#### A1 Electrical systems

Function and operation of a system, including:

- single phase alternating current (AC) supply, such as frequency, amplitude, rms value
- direct current (DC) supply, such as potential difference, current, resistance
- distribution, such as circuit protection and safety, types of circuit
- lighting, such as simple circuits, series and parallel connection, two-way circuit
- electrical plant, such as motor and starter, generator, compressor
- portable appliances, such as office equipment, isolating transformer.

Diagrammatic representation of the system, including:

- block diagram
- circuit diagram using IEC 60617 (BS3939) IEEE 315 graphical symbol standards.

#### A2 Electronic systems

Function and operation of a system, including:

- power supplies
- control systems, such as motor speed, position, temperature, flow
- communication systems, such as transmitters, receivers, transceivers, signal processing
- display systems, such as human computer interfaces (HCI)
- data network systems, such as local area network (LAN), wide area network (WAN).

Diagrammatic representation of the system, including:

- block diagrams
- circuit diagrams using IEC 60617 (BS3939) IEEE 315 graphical symbol standards.

#### A3 Electrical and electronic system components

Function and operation of components, including:

- passive components, such as resistor, capacitor, inductor (fixed value, variable, pre-set)
- active components, such as diode, transistor (bipolar and unipolar), integrated circuit
- circuit board, such as printed circuit board (PCB), connectors, heat sinks, switch, cabling, connector
- power supply, such as battery, transformer, regulated DC, inverter
- protection devices, such as fuse, circuit breaker
- lighting, such as lamps, luminaires
- sensors, such as thermocouple, thermistor, thermostat, position sensors (linear and rotary)
- actuators, such as solenoid, relay, motor, contactors, light emitting diode, sounder
- display panel

- mechanical fixings and fittings, such as nuts (locking, retaining), bolts, screws, drive belts.

## Learning aim B: Select components used in electrical and electronic systems during routine maintenance

### B1 Electrical and electronic system data

Sources of system information, including:

- circuit diagram
- assembly drawing
- parts schedule
- block diagram
- maintenance procedure, such as Standard Operating Procedure (SOP).

### B2 Component data

Sources of component data, including:

- manufacturer's catalogue
- data sheet
- repair manual
- parts list.

### B3 Component selection

- Selection of components to be used in a maintenance procedure, such as identifying physical components required by the parts schedule for the procedure.

## Learning aim C: Prepare for and safely carry out routine maintenance on electrical or electronic systems

### C1 Safety

Safety awareness while carrying out work on electrical and electronic systems, including:

- workplace hazards, such as electric shock, untidy work area, slips and trips, badly maintained tools and equipment, unfenced machinery, restricted workspace, toxic substances and fumes, flammable substances, biological (need for barrier creams and hand cleanser), working at heights, falling objects
- risk assessment, such as hazards and risks, people at risk, control measures and documentation.

Keeping safe in an electrical and electronic work environment, including:

- personal protective equipment (PPE)
- safe working practices, such as permit to work, danger tags, warning notices, safety barriers, isolation, treatment for eye injury (fluid and particle penetration) and other procedures in case of injury, accident reporting
- approved working procedures.

### C2 Routine maintenance tasks

Inspection checks and tests, including:

- visual examination, such as wear, chafing, fouling, evidence of overheating, security of attachment, missing or loose fittings
- performance, such as operating within specification
- electrical parameters, such as insulation test, continuity, current and voltage measurements, input/output
- adjustments, such as mechanical fittings and fixings, drive belts.

Maintenance procedures, including

- adjustments, such as security of fixtures and fittings
- replacing components, such as exchanging a printed circuit board (PCB)
- replacing/changing consumables, such as lubricant, printer ink cartridge
- testing against specification.

Recording actions, including:

- standard documentation, such as completing template job card, checklist, maintenance report, sign-off documentation.

## Learning aim D: Prepare for and safely carry out fault-finding and fault-rectification on electrical or electronic systems

### D1 Identification of faults in an electrical or electronic system

Types of fault, including:

- fault symptoms, such as complete breakdown, intermittent operation, overheating, out of specification, fault codes
- common faults, such as short circuit, open circuit, component failure.

Aids to determining faults, including:

- manufacturer's data, such as system specification, system diagram, functional and troubleshooting charts, component data sheets, operation and maintenance manual, fault codes
- previous records, such as fault/repair reports, software-based records and data, test and handover procedures
- instruments, such as multimeter, signal generator, insulation resistance tester, oscilloscope, logic probe, signal tracer, portable appliance tester, earth loop impedance tester, light meter, continuity tester.

Fault-finding techniques, including:

- visual examination
- six-point method (collect evidence, analyse evidence, locate fault, determine and remove cause, rectify fault, check system)
- input to output, output to input
- half split method
- unit substitution.

### D2 Fault rectification

Safe use of equipment, including:

- soldering tools, such as soldering iron, de-soldering tools
- hand tools, such as screwdrivers, pliers and crimping tools, hex keys, spanners.

Safe removal and replacement of faulty components, including:

- remove mechanical fixings, such as selecting correct tools to remove fixings and fastenings, unclipping electrical connectors
- remove faulty component, such as remove PCB, repair, source replacement, re-fit
- procedures, such as de-solder, re-solder
- post repair tests and checks, such as input to output check that the system is working.

Recording actions, including:

- standard documentation, such as completing template job card, checklist, fault and rectification report, sign-off documentation.

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## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Investigate the operation of electrical and electronic systems and the function and operation of components used in them</td><td rowspan="2">A.D1 Analyse the impact of components on the reliable operation of electrical and electronic systems.</td></tr>
<tr><td>A.P1 Describe the function of four different components in an electrical system.<br>A.P2 Describe the function of four different components in an electronic system.</td><td>A.M1 Explain the effect of components on the operation of an electrical system.<br>A.M2 Explain the effect of components on the operation of an electronic system.</td></tr>
<tr><td colspan="2">Learning aim B: Select components used in electrical and electronic systems during routine maintenance</td><td rowspan="4">BC.D2 Evaluate the selection of components and the effectiveness of a routine maintenance task on an electrical or electronic system carried out safely and independently.</td></tr>
<tr><td>B.P3 Select suitable components for a routine maintenance task on an electrical system or an electronic system.</td><td>B.M3 Explain the selection of electrical or electronic components for a routine maintenance task on an electrical or electronic system.</td></tr>
<tr><td colspan="2">Learning aim C: Prepare for and safely carry out routine maintenance on electrical or electronic systems</td></tr>
<tr><td>C.P4 Identify hazards and risks before carrying out a routine maintenance task on an electrical or electronic system.<br>C.P5 Prepare for and carry out a routine maintenance task safely on an electrical or electronic system.</td><td>C.M4 Prepare for and carry out a routine maintenance task on an electrical or electronic system safely and independently.</td></tr>
<tr><td colspan="2">Learning aim D: Prepare for and safely carry out fault-finding and fault-rectification on electrical or electronic systems</td><td rowspan="2">D.D3 Justify the techniques used in preparing for and carrying out a fault-finding and a fault rectification task on an electrical or electronic system safely and independently.</td></tr>
<tr><td>D.P6 Prepare for and carry out a fault-finding task on an electrical or electronic system safely with some assistance.<br>D.P7 Prepare for and carry out a fault rectification task on an electrical or electronic system safely with some assistance.</td><td>D.M5 Explain the techniques used in preparing for and carrying out a fault-finding and a fault rectification task on an electrical or electronic system safely and independently.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aims: B and C (B.P3, C.P4, C.P5, B.M3, C.M4, BC.D2)

Learning aim: D (D.P6, D.P7, D.M5, D.D3)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- a fully equipped workshop environment suitable for carrying out maintenance activities safely
- electrical and electronic systems on which to carry out maintenance, fault-finding and rectification activities
- test equipment, including oscilloscopes, signal generators, pulse generators, low voltage power supplies, logic probes and multimeters
- tools and safety equipment
- reference material including relevant manufacturers' service manuals, data sheets, component lists, drawings and diagrams and standard operating procedures.

## Essential information for assessment decisions

It is recommended that the electrical and electronic systems investigated and worked on are consistent throughout the assessments for this unit.

Learners must select components and carry out a routine maintenance task on either an electrical or an electronic system for learning aims B and C. Learners must use the alternative system for the fault-finding and rectification exercise for Learning Aim D. Therefore, if an electrical system is used for learning aims B and C, an electronic system must be used for learning aim D, and vice versa.

## Learning aim A

The electrical and electronic systems should each contain a minimum of four different components. The components must not be all the same type. They should represent passive components such as resistors, active components such as diodes, sensors such as thermostats, and actuators such as motors.

If a similar type of component is selected for both systems then there should be significant differences between them, for example a ceramic capacitor in an audio circuit and an electrolytic capacitor in a power supply circuit.

The systems should be complex enough to carry out routine maintenance, fault-finding and rectification exercises.

**For Distinction standard**, learners will:

- Produce evidence that demonstrates that they can accurately determine the function of components in an electrical and an electronic system.
- Demonstrate that they can analyse the effect of components on the operation of an electrical and an electronic system.
- Provide a written evaluation of the operation of an electrical and an electronic system. The evaluation will include the effects of component faults on the operating performance of both systems. Learners should consider system malfunction and the consequences if a system is not reliable.

**For Merit standard**, learners will:

- Produce evidence that demonstrates that they can determine the function of components in an electrical and an electronic system .
- Demonstrate that they can explain the effect of components on the operation of an electrical and an electronic system.
- Provide a written explanation of the operation of an electrical and an electronic system. The explanation will include the effects of component faults on the operating performance and reliability of an both systems.

**For Pass standard**, learners will:

- Produce evidence that demonstrates that they can describe the function of at least four different component types (e.g. not 4 resistors with different values) in an electrical system and at least four component types in an electronic system.
- Provide a written description of the operation of an electrical and an electronic system. The description will include the effects of component faults on the operating performance and reliability of at least one of the systems. The description will be mostly accurate but may contain some omissions or minor errors. Diagrams may come from a researched source but must be accompanied by the learner's 'own writing' and be referenced.

## Learning aims B and C

The assessment activity for learning aims B and C must include full details of the routine maintenance activity to be completed on either an electrical or an electronic system. It is recommended that the system is one of those investigated for learning aim A. The routine maintenance activity should include:

- a safety review of the activity
- a visual examination
- measurement of electrical parameters and performance
- replacement of a component or consumables
- use of standard documentation to record the activity.

**For Distinction standard**, learners will:

- Produce evidence that demonstrates that they can independently and accurately identify components to carry out maintenance activities on an electrical or an electronic system.
- Demonstrate a thorough understanding of safe working practices when working with electrical and electronic circuits.
- prepare for and carry out a thorough maintenance activity on either an electrical system or an electronic system. Any assistance from the tutor must be strictly limited to verbal confirmation that the learner is carrying out the work activity in a safe manner.
- Produce a written maintenance report evaluating the effectiveness of the maintenance activity on either an electrical system or an electronic system. The report will be logically structured and use correct technical engineering terms to provide precise and correct reference to selection of methods, tools and components.

**For Merit standard**, learners will:

- Produce evidence that demonstrates that they can independently identify components to carry out maintenance activities on an electrical and an electronic system.
- Demonstrate a good understanding of safe working practices when working with electrical and electronic systems.
- Prepare for and safely carry out an accurate maintenance activity on either an electrical system or an electronic system. Any assistance from the tutor must be limited to verbal confirmation that the learner is carrying out the work activity in a safe manner.
- Produce a written maintenance report explaining the maintenance activity carried out on either an electrical system or an electronic system. The report will be organised and provide correct reference to selection of methods, tools and components.

**For Pass standard**, learners will:

- Produce evidence that demonstrates that they can identify components to carry out maintenance activities on an electrical and an electronic system.
- Provide evidence to demonstrate understanding of safe working practices when working with electrical and electronic circuits.
- Prepare for and carry out a maintenance activity on either an electrical system or an electronic system. Learners may ask questions and seek and receive clarification while undertaking the construction activity themselves.
- Produce a written maintenance report describing the maintenance activity carried out. The report will be mostly accurate but may contain some omissions or minor errors. The activity will be carried out safely to a reasonable standard.

## Learning aim D

The assessment activity for learning aim D must include full details of the fault-finding and rectification activity to be completed on either an electrical or an electronic system. It is recommended that the system is one of those investigated for learning aim A and must be the alternative type to the one used for learning aims B and C.

The fault-finding and rectification activity should include:

- a single common fault
- a visual examination and the use of at least one other fault-finding technique
- use of at least two reference aids
- safe use of at least two measuring instruments (using a multimeter to measure voltage and current is equivalent to two instruments).
- safe removal and replacement of a faulty component
- use of standard documentation to record the activity.

**For Distinction standard**, learners will:

- Prepare for and carry out a fault-finding and repair activity on an electrical or electronic system safely, independently and effectively. Any assistance from the tutor must be strictly limited to verbal confirmation that the learner is carrying out the work activity in a safe manner.
- Carry out measurements safely and accurately using the most appropriate instruments, justifying the selection of instruments and methods used.

- Produce a well-organised fault-finding report justifying the techniques used in finding and rectifying a fault in an electrical or electronic system. Overall, the evidence will be structured logically and use correct technical engineering terms.

**For Merit standard**, learners will:

- Prepare for and carry out a fault-finding and repair activity on an electrical or electronic system safely and independently. Any assistance from the tutor must be strictly limited to verbal confirmation that the learner is carrying out the work activity in a safe manner.
- Carry out measurements safely and accurately on an electrical or electronic system using appropriate instruments. Learners should explain the selection of instruments and methods used.
- Produce an organised fault-finding report explaining the techniques used in finding and rectifying a fault in an electrical or electronic system in some detail. Overall, the evidence will be structured logically and use mainly correct technical engineering terms.

**For Pass standard**, learners will:

- Prepare for and carry out a fault-finding and repair activity on an electrical or electronic system safely with a minimum of support. Learners may ask questions and seek and receive clarification while undertaking the fault-finding and repair themselves.
- Carry out measurements safely on an electrical or electronic system using an appropriate measuring instrument.
- Produce a fault-finding report describing the techniques used in finding and rectifying a fault in an electrical or electronic system. The description will be mostly accurate but may contain some omissions or minor errors. The activity will be carried out safely to a reasonable standard.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 22: Electrical and Electronic Circuit Construction and Testing
- Unit 23: Electronic Devices and Communication Applications.

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### Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into industrial techniques, the importance of safety in maintenance planning and implementation and the need to maintain accurate records
- guest speakers from professional bodies to share insights into the importance of the maintenance technicians and engineers in keeping industry productive
- documentation, such as a range of circuit drawings, electrical/electronic specifications, data sheets and standard operating procedures
- access to electrical and electronic systems, such as systems that have been replaced by updated hardware
- work experience that will allow learners to become familiar with typical industrial environments. The nature of the knowledge and skills being developed in this unit mean that it is particularly suited to incorporating a period of work experience. Learners could, for example, shadow a maintenance technician carrying out routine maintenance and rectification activities.

### Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

#### Problem solving

- Selecting the most appropriate techniques and equipment to safely carry out fault-finding and rectification activities.

#### Managing information

- Collecting, recording and interpreting data from various sources.

#### Self-management and development

- Development of skills relating to carrying out practical exercises will be self-managed by learners.

# Unit 25: Computer Numerical Control Programming and Machining

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will develop CNC (Computer Numerical Control) part programs to manufacture accurate components on CNC machine tools safely.

## Unit introduction

Have you ever wondered how complex machined components are manufactured to such a high degree of accuracy, from small gear mechanisms for bicycles to large jet engines for aeroplanes? The answer is with the help of computers and specifically CNC, which stands for Computer Numerical Control.

CNC is used extensively throughout the engineering industry as a means of producing precisely controlled movements. Its main application in engineering is in the production of components using machine tools for material removal. Typical examples of these machine tools include CNC lathes, milling machines and routers. CNC has revolutionised the engineering environment in many ways – in particular, it has helped to improve productivity, flexibility and quality.

This unit will provide you with an introduction to CNC part programming and machining. It will enable you to plan for the manufacture of a component to be made using a CNC machine tool, based on its specification. You will learn how to write a part program for safe use on a CNC machine tool. You will also learn how CNC machine tools use these programs and how, by running part programs, components can be accurately and consistently produced, complying with all relevant health and safety regulations. An important part of this process is the development of an accurate part program and you will gain experience of proofreading CNC programs, checking products are being made correctly and adjusting where necessary.

## Learning aims

In this unit you will:

**A** Investigate CNC machine tools and their safe use

**B** Develop part programs and safely manufacture components using CNC machine tools

**C** Check the compliance and accuracy of components manufactured using CNC machine tools.

## Summary of unit

<table>
<tr><th>Learning aim</th><th>Key content areas</th><th>Assessment approach</th></tr>
<tr><td>A Investigate CNC machine tools and their safe use</td><td>A1 CNC machine tools<br>A2 Safety</td><td>A report with annotated images/diagrams/photographs to detail how CNC machine tools are used safely for manufacturing processes in relationship to the differences to manual machine tools.</td></tr>
<tr><td>B Develop part programs and safely manufacture components using CNC machine tools</td><td>B1 Component specification and planning manufacture<br>B2 CNC part programming<br>B3 Run part programs on a CNC machine tool<br>B4 Working safely</td><td rowspan="2">A practical activity involving the planning, part program creation, simulation, safe setting-up, manufacture and quality checking of a workpiece made using CNC machining. The assessment evidence will include the finished workpiece and a logbook with set-up, planning notes, part programmes and quality documents, annotated photographs and/or videos with learner narration, quality control records and learner observation records/witness statements.</td></tr>
<tr><td>C Check the compliance and accuracy of components manufactured using CNC machine tools</td><td>C1 Checks for compliance and accuracy</td></tr>
</table>



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# Content

## Learning aim A: Investigate CNC machine tools and their safe use

### A1 CNC machine tools

The types, characteristics, programming and uses of CNC machine tools including:

- types, such as lathes, milling machines, routers, plasma cutters, machining centres
- characteristics and the main differences to manual machine tools, such as computer control, carrying out multiple operations, time to set-up and machining time, accuracy, consistency, skills of the operator
- programming procedures – manual data input (MDI), downloading, CAD/CAM, storing and retrieving programs, editing
- uses for engineering applications – prototyping, one-offs, complex parts, small and large batches.

### A2 Safety

The safe use of CNC machine tools including:

- specific safety features, such as emergency stops, interlocking guards
- other features that enhance safety, such as tool changers, bar feeds, in-built inspection, automation systems, tool path simulations/dry runs.

## Learning aim B: Develop part programs and safely manufacture components using CNC machine tools

### B1 Component specification and planning manufacture

Using and producing the documentation required to be able to develop a CNC part program, including:

- component specification, such as engineering drawings, quality details, production quantities and delivery rates
- planning for manufacture, such as type of CNC machine tool required, materials required, cutting tools required, speeds and feeds appropriate to given materials, suitable sequences of machining operations, avoidance of wasted tool/cutter movements and tool changes.

### B2 CNC part programming

Writing part programs for a CNC machine tool based on the component specification and plan for manufacture, covering details such as:

- reference (datum) points
- absolute co-ordinates
- machine axes
- positional information using absolute systems of measurement
- tool change positions
- tool lengths
- units
- canned cycles
- sub-routines
- axis co-ordinates (x, y, z)
- safety
- G Codes, M Codes.

### B3 Run part programs on a CNC machine tool

Loading, simulating and running part programs on a CNC machine tool, including:

- storing and retrieving programs using portable media or networks
- downloading via computer interface
- manual data input (MDI)
- inserting materials and tools
- setting datums
- setting tooling and offsets
- setting spindle speeds
- setting feed rates
- using on-screen simulations and step-by-step dry runs for proofing
- using speed and feed overrides.

### B4 Working safely

General safety awareness while using a CNC machine tool, including:

- identifying hazards
- use of personal protective equipment (PPE)
- emergency stop
- interlocking guards
- speed and feed overrides
- keeping a clean and tidy work area.

## Learning aim C: Check the compliance and accuracy of components manufactured using CNC machine tools

### C1 Checks for compliance and accuracy

Visual and specific checks for compliance and accuracy using suitable tools and equipment to ensure:

- CNC part programs and machine tool settings can be adjusted so that components are machined accurately and are not undersize
- quality records are available
- no false tool cuts, burrs or sharp edges are evident
- dimensions are within linear tolerances
- surface roughness is as or better than required.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Investigate CNC machine tools and their safe use</td><td rowspan="2">A.D1 Justify the use of a CNC machine tool rather than a manual machine tool to safely, efficiently and effectively manufacture a component.</td></tr>
<tr><td>A.P1 Describe the main differences between a CNC machine tool and a manual machine tool.<br>A.P2 Describe the safety features of a CNC machine tool.</td><td>A.M1 Compare and contrast the use of a CNC machine tool and a manual machine tool to safely manufacture a component.</td></tr>
<tr><td colspan="2">Learning aim B: Develop part programs and safely manufacture components using CNC machine tools</td><td rowspan="4">BC.D2 Produce an accurate component on a CNC machine tool safely and efficiently following a comprehensive plan, and by refining the part program during simulation and using recorded checks to adjust settings during manufacture.</td></tr>
<tr><td>B.P3 Plan the manufacture of a component to be made using a CNC machine tool.<br>B.P4 Create a part program for the manufacture of a component to be made using a CNC machine tool.<br>B.P5 Load a part program created to simulate the manufacture of a component to be made using a CNC machine tool.<br>B.P6 Run a part program to safely manufacture a component on a CNC machine tool.</td><td>B.M2 Develop a detailed plan and part program to simulate and then safely manufacture a component on a CNC machine tool.</td></tr>
<tr><td colspan="2">Learning aim C: Check the compliance and accuracy of components manufactured using CNC machine tools</td></tr>
<tr><td>C.P7 Carry out and record compliance and accuracy checks on a component manufactured using a CNC machine tool.</td><td>C.M3 Carry out and record checks to establish compliance and accuracy during and after the manufacture of a component using a CNC machine tool.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aims: B and C (B.P3, B.P4, B.P5, B.P6, C.P7, B.M2, C.M3, BC.D2)

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# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- suitable software to be able to develop a CNC part program
- at least one type of CNC machine tool that can be programmed, where learners can, for example, set the offsets/tool changes – these may be lathes, milling machines, routers etc.
- a suitable range of materials, tooling and work-holding devices.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Justify why they have chosen a CNC machine tool to manufacture a component, in preference to a manual machine tool, in terms of safety, its efficiency and effectiveness.
- Provide a justification to show precise and correct reasons why the chosen CNC machine tool is the most appropriate to manufacture the component, by referring to the features and characteristics and main differences of the CNC machine tool and the manual machine tool. Considering alternative manual machine tools and giving reasons why the manual machine tool was considered less suitable than the CNC machine tool chosen, for example with a suitable justification, a CNC machining centre may be chosen for a complex shaft that requires turning operations and keyway milling, rather than using a manual lathe then a milling machine.

**For Merit standard**, learners will:

- Provide an account of the similarities and differences of the use of a CNC machine tool to safely manufacture a component, in preference to a manual machine tool.
- The similarities and differences will provide an accurate set of advantages and disadvantages by referring to the features, safety aspects, and characteristics in operation whilst manufacturing a component, on a CNC machine tool and manual machine tool, for example they may highlight that manual machine tools are better for one off components, but this is not always the case for extremely complicated products, such as a turbine blade, without preparing specialist work holding devices.

**For Pass standard**, learners will:

- Provide information on the main differences between a CNC machine tool and a manual machine tool. They may not be the main differences between CNC machine tools and manual tools, for example they might describe that creating a ground form tool for a manual machine to create non-standard radii is preferable to programming and they might choose to offset a tailstock on a centre lathe to create a taper rather than using a line of code on a CNC program.

- Provide information on the safety features of the CNC machine tool. The descriptions will be specific to a CNC machine tool, such as in-built inspection systems that monitor size and tool wear during the manufacturing process that safely operate behind interlocked machine guards, or limit speeds and feeds to 20 per cent on the first run, using the feed and speed override.

### Learning aims B and C

The component to be manufactured on a CNC machine tool must have a range of features, for example:

- a shaft with different diameters, radii, tapers, and chamfers
- a block with several slots, radii, tapers, and diameters
- a housing with several steps, radii, tapers, and chamfers.

**For Distinction standard**, learners will:

- Produce effectively, safely, and accurately on a CNC machine tool a component from a comprehensive interpretation of the specification to create a plan, showing adaptability and a clear understanding of their importance by modifying them, based on, for example, simulation, dry runs, and machine feedback. For example, to reset the workpiece datum, set new tool offsets, or speeds and feeds to ensure that the component is compliant and accurate when complete.
- Create comprehensive planning documentation to interpret the specification accurately that shows most appropriate information for the operational sequence, tooling, machine requirements, and workpiece orientation.
- Create an accurate part program using manual CNC programming, G and M codes, (not CAD/CAM generated) that follows the plan to machine the product safely and efficiently. Simulate and refine the part program whilst gathering data during simulation and trial runs.
- Set up the tooling accurately to the tooling sheets created and carry out CNC machining processes with a high level of skill. They will show the capability to manipulate CNC machines, tools, equipment and work-holding devices to machine a product in an efficient manner.
- Carry out all relevant and necessary quality checks in an accurate manner both during and after the production of the machined workpiece. They will generate detailed and correct quality records to show that they carried out all relevant and necessary quality checks and that they adapted their approach based on the information provided to ensure the compliance and accuracy of the workpiece. Quality checks during manufacture may record the accuracy of tool setting, and workpiece datums.
- Demonstrate compliance with safe working practices throughout all of the machining activities.

**For Merit standard**, learners will:

- Produce safely on a CNC machine tool a component from a detailed interpretation of the specification to create a detailed plan, and simulation, to attain the necessary levels of compliance and accuracy.
- Create detailed planning documentation to interpret the specification that shows appropriate information for the operational sequence, tooling, machine requirements, and workpiece orientation. Some choices may be sub-optimal, for example roughing operations may be set with shallow depth of cuts, increasing the machining times.

- Create a part program using manual CNC programming, G and M codes, that follows the plan to machine the product safely. Load and simulate the part program to determine the safety of the programme. For example they may use inappropriate tool changes that are not in the safe zone, manufacture in an incorrect order or use sub-optimal programming.
- Set up the tooling and datums to the tooling sheets created and carry out CNC machining processes with a level of skill. There may be some instances where parameters are not effectively set, monitored, and adjusted, leading to minor quality issues, such as an unimportant, shallow false cut due to not retracting the tool after a finishing cut, that can be reprogrammed and machined correctly.
- Carry out visual and specific quality checks in an accurate manner both during and after the production of the machined workpiece. They will generate suitable quality records to evidence the visual and specific quality checks carried out. They may not always carry out the quality checks at appropriate times during production of the workpiece, leading to minor quality issues such as incorrectly blending a radius on a feature. Quality checks during manufacture may record the accuracy of tool setting, and workpiece datums.
- Demonstrate compliance with safe working practices throughout all of the machining activities.

**For Pass standard**, learners will:

- Produce safely on a CNC machine tool a component from an interpretation of the specification to create a plan and simulation, to attain the necessary levels of compliance and accuracy.
- Create planning documentation to interpret the specification that shows appropriate information for the operational sequence, tooling, machine requirements, and workpiece orientation. Some choices may be initially incorrect, for example operational sequences may be incorrect, such as tapping prior to drilling.
- Create a part program using manual CNC programming, G and M codes, that follows the plan to machine the product safely. Load and run the part program using simulation to determine the part program is safe to run, for example they may program inappropriate tooling.
- Set up the tooling and datums to the tooling sheets created and carry out CNC machining processes with some skill. There may be some instances where speeds and feeds are not calculated correctly, monitored and adjusted, leading to quality issues, such as poor finishes, and damaged tooling.
- Carry out quality checks of the machined workpiece. They will generate quality records to evidence the quality checks carried out. They may not always carry out relevant and accurate quality checks at appropriate times during production of the workpiece and may fail to recognise the significance of the information provided, for example accurate tool setting is critical to ensure the tooling achieves the required programmed sizes.
- Demonstrate compliance with safe working practices throughout all of the machining activities.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 2: Engineering Thinking Skills to Create Solutions
- Unit 7: Engineering Drawing
- Unit 17: 3D Printing.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry to share insights into industrial CNC machining techniques, the diversity of CNC: machining centres, lathes, milling, EDM, plasma within a range of engineering sectors
- visits to industrial workshops to encounter CNC machine tools in real world environments
- the importance of safety in CNC machining, the importance of quality checks on workpieces and the need to maintain accurate quality records
- documentation, such as a range of simple and complex engineering drawings and associated workpieces, that have been produced in one machining cycle on a CNC machine
- work experience, which will allow learners to become familiar with industrial CNC machining techniques and the typical industrial environments in which they are used. The nature of the knowledge and skills being developed in this unit mean that it is particularly suited to incorporating a period of work experience. Learners could, for example, shadow a CNC machinist and programmer, when developing programs for machined parts.
- a CNC machine operator or supervisor, to support practical lessons and to provide feedback and developmental advice to learners as their skills develop. This would help to ensure that the machining techniques are taught effectively and mirror those in current use in industry.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate techniques, tooling, and work-holding devices to manufacture features on workpieces.

### Managing information

- Collecting, recording, and interpreting quality data.

### Self-management and development

- Development of planning, programming and practical skills relating to CNC processes will be self-managed by learners.

# Unit 26: Robotics

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will be introduced to the types, applications and operating principles of robotic arms and systems. They will also develop a program for a robotic arm.

## Unit introduction

Robotics is at the forefront of the latest industry developments across a range of engineering sectors. Industrial robots are used within heavy production environments such as car assembly, as well as light industry such as printed circuit board (PCB) assembly. Robots are also being introduced into ancillary operations such as picking, packing, test and inspection.

This unit provides learners with an insight into a number of possible job roles, including robot programming engineer, allowing the learner to understand the specific terms and techniques associated with working on a robotic system. This in turn will prepare them for a trainee or apprentice role in this field, or further study in this subject area.

## Learning aims

In this unit you will:

**A** Investigate the types and applications of industrial robotic arms

**B** Investigate the operating principles of industrial robotic arms and systems

**C** Develop a program for a robotic arm that will perform an engineering operation.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate the types and applications of industrial robotic arms | **A1** Applications for robotic arms<br>**A2** Benefits and drawbacks of using robotic arms | A report for two chosen robotic arms/systems comprising:<br>· The steps of the automated process<br>· The benefits and drawbacks of automating the process<br>· An annotated diagram of the robot arm/system used<br>· A description of the end effector(s) in use<br>· The safety systems and safe working practises being used. |
| **B** Investigate the operating principles of industrial robotic arms and systems | **B1** Component parts of a robotic arm/system<br>**B2** Different end effectors used on robotic arms<br>**B3** Safe and effective working practices with robotic arms/systems | |
| **C** Develop a program for a robotic arm that will perform an engineering operation | **C1** Principles of programming a robotic arm<br>**C2** Creating a program for a robot arm<br>**C3** Editing a program for a robot arm | A practical activity, involving the safe setting up, programming and testing of a robotic arm within a given engineering scenario. Assessment evidence can include an audio-visual recording of the robot program running correctly. |

# Content

## Learning aim A: Investigate the types and applications of industrial robotic arms

### A1 Applications for robotic arms

- Industrial applications of robotic arms, including:
  - car production: material handling, welding, gluing, paint spraying
  - distribution: packing, palletising
  - small-scale manufacture: pick and place, printed circuit board (PCB) manufacture
  - consumer goods, food and beverage.
- Types of robotic arm, including:
  - industrial robots, e.g. articulated robots, cartesian and cylindrical
  - selective compliance assembly robot arm (SCARA)
  - collaborative.

### A2 Benefits and drawbacks of using robotic arms

Comparison of benefits and drawbacks of using robotic arms to similar manual processes that do not contain automation.

- Benefits of using robotic arms including:
  - financial
  - quality
  - reliability
  - accuracy
  - use in hazardous areas
  - speed of manufacture.
- Drawbacks including:
  - reduction/replacement of human workforce
  - increased health and safety requirements
  - initial cost
  - specialist knowledge for programming and installation.

## Learning aim B: Investigate the operating principles of industrial robotic arms and systems

### B1 Component parts of a robotic arm/system

Operating principles of robotic arm/system including:

- robot arm, controller, teach pendant, external control (e.g. PLC)
- degrees of freedom/axes
- wervo control positional feedback.

### B2 Different end effectors used on robotic arms

Operating principles of end effectors in different applications including:

- material handling/pick and place applications, including those using a gripper, suction and custom gripper assemblies
- jointing operations applications, e.g.: riveting, screwdriving, welding and glueing/sealing

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- specialist operations, e.g. liquid dispensing, painting and material removal (deburring, drilling)
- types of power, including electrical, pneumatic and hydraulic.

**B3 Safe and effective working practices with robotic arms/systems**

- Hazards working with robotic arms including e.g.: danger to programmers when programming and testing, danger to operators from moving robotic arms and industrial processes like welding.
- Suitability of modes of operation to mitigate hazards, including:
  - teach mode
  - run/auto mode
  - teach mode full speed.
- Suitability of physical safety measures to mitigate hazards, including:
  - guarding
  - safety barriers/fences
  - interlocks on operator access points
  - emergency stop buttons.
- Suitability of electronic safety measures to mitigate hazards, including:
  - light curtains
  - floor scanners
  - pressure pads.

## Learning aim C: Develop a program for a robotic arm that will perform an engineering operation

**C1 Principles of programming a robotic arm**

- Position references, including:
  - work object
  - base/world co-ordinate system
  - tool co-ordinate system
  - Cartesian coordinates, including Tool Centre Point (TCP).
- Movement types, including:
  - joint
  - linear
  - circular.
- Programming methods, including:
  - offline/simulation
  - online.

**C2 Creating a program for a robot arm**

- Using a teach pendant to manually move the robot arm.
- Compiling a sequence of points into a robot program.
- Adding output commands to operate an end effector as appropriate.
- Testing and optimising the program.
- Saving the program and reloading.



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**C3 Editing a program for a robot arm**

- Adding/editing places within a program.
- Editing parameters/data within a program, including:
  - motion type
  - velocity
  - co-ordinates.
- Testing and optimising the modified program, including:
  - debugging
  - live operation without and with workpieces
  - incrementing operating velocities.
- Saving the modified program.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate the types and applications of industrial robotic arms** | | |
| **A.P1** Describe adequately the processes being undertaken by two different industrial applications using robotic arms, identifying the main benefits of each application. | **A.M1** Describe in detail the processes being undertaken by two different industrial applications using robotic arms, comparing the benefits and drawbacks of each. | **AB.D1** Evaluate the use of robotic arms/ systems for two different industrial applications, including the suitability of component parts, end effector(s), and the safe working practices. |
| **Learning aim B: Investigate the operating principles of industrial robotic arms and systems** | | |
| **B.P2** Outline the operating principles for two different industrial robotic arms/ systems, including the end effector(s) used.<br>**B.P3** Identify hazards and the safe working practices being used on two different industrial robotic arms/systems. | **B.M2** Describe in detail the operating principles, hazards and safe working practices for two different industrial robotic arms/systems, justifying the suitability of the end effector(s). | |
| **Learning aim C: Develop a program for a robotic arm that will perform an engineering operation** | | |
| **C.P4** Plan how to use a robot arm to perform an engineering operation safely.<br>**C.P5** Produce functional programming for a robot arm that operates safely to perform part of a given engineering operation. | **C.M3** Develop functional programming for a robot arm that operates safely to perform a given engineering operation correctly. | **C.D2** Optimise functional programming for a robot arm that operates safely to perform a given engineering operation efficiently. |



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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aim: C (C.P4, C.P5, C.M3, C.D2)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners will need access to a robotic arm capable of:

- jogging, by using a teach pendant or equivalent, into suitable positions to perform tasks representative of those found in industry (e.g. pick and place)
- moving using no less than two co-ordinate systems to include joint and linear – or the manufacturer's equivalent of these (e.g. linear may be referred to as cartesian, x-y etc.)
- operating at least one type of end effector suitable for replicating an industrial process (e.g. gripper, vacuum cup)
- being programmable, to the extent of allowing learners to enter programs consisting of a sequence of predefined points.

### Essential information for assessment decisions

### Learning aims A and B

**For Distinction standard**, learners will:

- Evaluate why two different industrial applications have been automated using robots. They will include:
  - an explanation of all the process steps being undertaken for each application, including the robot workspaces, for example how parts arrive to and depart from the work area. They will also explain the benefits and drawbacks of using robotic arms in each situation and will make comparisons to a non-automated alternative manual process
  - a block diagram and annotation of each robot system with an explanation of the operating principles, including (as applicable) the robot arm, robot controller, teach pendant, control signals to the robot, feedback signals from the robot
  - a technical description and the operating principles of the end effectors used in the application and a justification of their suitability for the task
  - identification of the hazards presented by each application together with the suitability of the solutions employed to mitigate the associated risks.
- Learners will use appropriate technical language with accuracy and provide a balanced evaluation for each application throughout, and a conclusion about why the two applications have been automated.

**For Merit standard,** learners will:

- Describe in detail the processes being undertaken for two different industrial applications using robotic arms. The description will cover all the process steps and any omissions or inaccuracies will be minor. They will also compare the relative benefits and drawbacks resulting from the installation of the industrial robots.
- Describe in detail the operating principles of the robotic arms and systems including (as applicable) the robot arm, robot controller and teach pendant. They will provide an annotated block diagram of each robot system, a detailed technical description of the end effectors used in each application and will justify their suitability for the task. Any omissions or inaccuracies will be minor.
- Describe in detail the hazards presented by each application together with the solutions that have been employed to mitigate the associated risks.

**For Pass standard,** learners will:

- Describe adequately the processes being undertaken for two different industrial applications using robotic arms. They will include the main benefits of using robotic arms and the descriptions may lack detail in places, for example they may miss minor steps within the process. There may also be some omissions or inaccuracies in the descriptions, however the descriptions will be relevant to the situations given.
- Outline (describe briefly) the operating principles of the robotic arms and systems. They will provide a block diagram of each robot system, which may lack annotation, and an outline description of the end effectors used in each application. Again, there may be some omissions or inaccuracies, however it will be relevant to the situations given.
- Identify the main hazards present and the safe working practices used within each application. This will take the form of a list and may contain some minor omissions or inaccuracies, but it will be relevant to the situation given.

## Learning aim C

Learning aim C requires learners to be given a suitable industrial scenario for a robotic arm. For example:

- material handling, e.g. taking a small sheet of metal from an upright holder and laying in onto a work surface to represent automotive panels being handled
- 3D pick and place, e.g. taking three plastic blocks from one area and stacking them in another area representing shelf stacking/palletising
- 2D pick and place, e.g. taking three plastic blocks from one area and accurately placing them into predefined positions, representing components being placed onto a printed circuit board
- adhesive application, e.g. using a pen to describe a pattern onto a piece of paper, representing laying down of adhesive
- material finishing, e.g. using a pen to trace a shape around a 2d object, representing a machine tool deburring a work object.

**For Distinction standard**, learners will:

- Develop a robotic program capable of completing a given engineering operation representative of an industrial scenario.
- They will:
  - plan the activity to be undertaken. Specific attention will be given to ensuring that appropriate safety measures are considered in both the programming and running phases
  - develop a functioning program, which fully meets the operational requirements given in the scenario. The use of the correct co-ordinate systems (for example, linear and joint) for each part of the task. An optimised robot program, working effectively and efficiently, as demonstrated by testing and recording the performance of the program over a number of iterations
  - demonstrate compliance with safe working practices throughout the program creation, testing and demonstration process.

**For Merit standard**, learners will:

- Develop a robotic program capable of completing a given engineering operation representative of an industrial scenario.
- They will:
    - plan the activity to be undertaken. Specific attention should be given to ensuring that appropriate safety measures are considered in both the programming and running phases
    - develop a functioning program for a robot arm, which fully meets the operational requirements given in the scenario. The test results/demonstration will show that the program meets the requirements
    - demonstrate compliance with safe working practices throughout the program creation, testing and demonstration process.

**For Pass standard**, learners will:

- plan the activities to be undertaken for a given engineering operation representative of an industrial scenario. Specific attention should be given to ensuring that appropriate safety measures are considered in both the programming and running phases. The plan may contain some omissions or inaccuracies, but these must not be related to safety and the plan will be relevant to the situation
- produce a functioning program for a robotic arm, which meets some of the operational requirements given in the scenario. The test results/demonstration will define the extent to which the program meets the operational requirements
- demonstrate compliance with safe working practices throughout the program creation, testing and demonstration process.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 28: Automated Systems.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- visits to automated production facilities (e.g. automotive plant) to see robotic automation in practice
- visits from automation professionals (e.g. robot programmers, installation engineers, project engineers, project managers) to add context to how and why industrial processes are automated.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate coordinates, trajectories and movement types to develop a working robot program.

### Self-management and development

- Development of practical skills relating to robot programming will be self-managed by learners.

# Unit 27: General Programming

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will develop knowledge and skills in computer programming, also known as software development as this is an integral part of many engineering organisations. Even organisations that do not produce software products, still rely on programmers to create bespoke and in-house solutions.

## Unit introduction

In this unit, you will learn how programming activities are carried out in engineering organisations; what the stages are in the software design and development process; and about the testing and delivery of a software program.

You will also design and develop a software program to satisfy user requirements and produce documentation to accompany your program. You will design and develop the software program using a suitable programming language and test and refine your solution.

An understanding of how computer programs work is essential knowledge for engineers looking to work in software development, meaning that this unit will help you prepare for employment or further studies.

## Learning aims

In this unit you will:

**A** Examine tools and techniques used in the development of a software program

**B** Design software programs to satisfy user requirements

**C** Develop software programs to satisfy user requirements.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Examine tools and techniques used in the development of a software program | **A1** Programming language paradigms<br>**A2** Programming techniques<br>**A3** Development tools | A report as a general overview of what programming is, covering paradigms, techniques and development tools. |
| **B** Design software programs to satisfy user requirements | **B1** Design tools<br>**B2** Planning to test | Portfolio containing an overview of the user requirements, and design documentation. User interface mock-ups annotated and a test report. |
| **C** Develop software programs to satisfy user requirements | **C1** Task planning<br>**C2** Development<br>**C3** Testing | Evidence of structured approach to task planning, such as a simple timeline. Recordings of working software, provision of source and instructions to build for the assessor. Results of developer testing and unit testing. |



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# Content

## Learning aim A: Examine tools and techniques used in the development of a software program

### A1 Programming language paradigms

- Procedural – a program in which the flow is driven by a set of instructions.
- Object-orientated – a program that is built up of objects which have their own parameters and actions.
- Event driven – a program in which the flow is driven by events, e.g. clicks, presses, keys, sensors, ticks, custom events.

### A2 Programming techniques

Sequencing, selection and iteration.

- Sequencing – sets of instructions to carry out a task or part of a task.
- Selection – asking questions and making decisions, directing the program to the target action or outcome:
  - IF statements
  - IF...ELSE statements
  - Switch...Case statements.
- Iteration – repeating an action in a certain number of steps to simply the overall action:
  - While and Do-While
  - For and For Each.
- Parameters or variables – naming conventions, by value and by reference, including:
  - Common data types – such as string, integer, Boolean, double.
- Arrays and lists:
  - use of arrays and lists, including initialisation, allocation of memory, getting and setting with an index
  - comparing arrays and lists:
    - Arrays are collections of data of the same data type
    - Lists are collections of data of different data types.
- Functions and procedures, to include:
  - return types – values to return from functions to the caller
  - parameters – values to provide to a function to affect the outcome
  - recursion – methods that call themselves with different or modified data.
- Operators, including:
  - arithmetic, such as +, -, *,/and MOD
  - relational Logic, such as equal to, greater than, greater than or equal to, less than, less than or equal to, and not equal to
  - Boolean logic, true and false in conjunction with AND, OR, NOT and XOR.
- Scope of methods and parameters, such as private, public and protected.

### A3 Development tools

- Assemblers, compilers and interpreters.
- Integrated development environments.
- Code editors.
- Compiler and build tools.
- Software development kits – sets of tools and software allowing development on and for a specific system.
- Libraries – collections of code that perform specific actions or provide additional functionality.
- Debuggers – processes to allow a developer to interact with the source code during the execution of the program:
  - stepping – the process of moving line by line through the code as it executes
  - break points – points at which the execution of the program stops or pauses for interrogation.
- Errors and error handling, including:
  - syntax and runtime errors
  - handling techniques, such as try and catch
  - common exceptions, such as null references and stack overflow.

## Learning aim B: Design software programs to satisfy user requirements

### B1 Design tools

- Evaluation of user requirements, such as what does the user want and why do they want this, for example:
  - what: an engineering company wants an application to post social media updates from its internal management system without having to post on each social media site individually
  - why: having to visit each site individually is time consuming and wasteful.
- Translation of user requirements into:
  - flow charts, including states and decisions to be made within the solution
  - UI designs, including global and specific styles, on-screen instructions, e.g. mock-ups, screenshots, images and sketches.

### B2 Planning to test

- Test lans and scripts:
  - for expected and unexpected conditions for the software program in operation
  - steps to recreate unexpected issues
- Unit tests:
  - testing individual parts of the software with specific and targeted developer tests

## Learning aim C: Develop software programs to satisfy user requirements.

### C1 Task Planning

- Granular tasks, including breaking down of a requirement into phases of development, such as:
  - create user interface
  - create events for user interface interactions
  - create methods for desired actions
  - link methods to events.

- Developer estimates:
  - estimate the time in hours that would be spent on a specific task
  - comparison of estimated time vs actual time, including importance of accurate estimates such as budgeting, resource planning.
- Roadmapping, identifying features in the plan that could be moved to a future phase, being able to identify which requirements are the minimum to meet the customer's requirements, for example, features that add value but are not part of the customer's initial requirements and being able to define that minimum viable product (MVP).

**C2 Development**

Language choice for target solution and factors that influence choice, including:

- Platform, such as:
  - web – ASP.NET, PHP, MVC, JavaScript
  - desktop or mobile:
    - target operating System, e.g.
    - Windows – .NET Framework, .NET Core
    - Linux – C, Mono.NET, Java, Python
    - OSX/iOS – Cocoa, Swift
  - IoT Device – .NET Core, C, Python.
- Comments and annotation:
  - description of methods and parameters.

**C3 Testing**

Types of testing, to include:

- Functionality and usability testing:
  - against user stories
  - against test scripts.
- Regression testing and reporting:
  - summary of testing – including pass/failed/skipped details
  - steps to reproduce in event of fail
  - actual and expected scenarios.
- Destruction testing:
  - unscripted testing on the solution
  - finds undocumented issues
  - fix and feed any found issues into regression test script.

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## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Examine tools and techniques used in the development of a software program** | | **A.D1** Evaluate the purpose and importance of the tools and techniques used in the development of a software program. |
| **A.P1** Describe the tools used in the development of a software program.<br>**A.P2** Describe the techniques used in the development of a software program. | **A.M1** Explain the purpose of the tools and techniques used in the development of a software program. | |
| **Learning aim B: Design software programs to satisfy user requirements** | | **BC.D2** Design, plan, develop and test a software program, using a range of software tools and techniques and ensure that it meets user requirements and operates as intended without any errors. |
| **B.P3** Design a software program to meet user requirements.<br>**B.P4** Devise test scripts to ensure a software program meets user requirements. | **B.M2** Design a software program using an effective user interface.<br>**B.M3** Devise a range of tests, identifying potential pitfalls, to ensure a software program meets user requirements and functionality. | |
| **Learning aim C: Develop software programs to satisfy user requirements** | | |
| **C.P5** Plan the development tasks for software programming.<br>**C.P6** Develop software programming using programming techniques and development tools. | **C.M4** Plan and develop software programming with an effective user interface, using designs and different techniques and tools to enable the testing of user requirements and to confirm it operates. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aims: B and C (B.P3, B.P4, C.P5, C.P6, B.M2, B.M3, C.M4, BC.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- modern, industrial programming, preferably a multi-paradigm language
- commercial/free software management tools.

## Essential information for assessment decisions

## Learning aims A

**For Distinction standard**, learners will:

- Provide a comprehensive evaluation on the tools and techniques used within the development of a software program.
- Describe each tool and technique in the unit content, giving appropriate and realistic examples of use.
- Compare similar tools and techniques and suggest scenarios where one tool or technique may be chosen over another.

Overall, learner's evidence will be easy to read and understood by a third party who may be an apprentice software engineer. It will be structured logically and use the correct terminology for engineering and programming.

**For Merit standard**, learners will:

- Compare the different and similar tools and techniques commonly used within the development of a software program.
- Explain the purpose and importance of each tool and technique.
- Justify the choice of selection with respect to its readability, complexity and effectiveness within the program.

Overall, learner's evidence will be structured logically, technically accurate and easy to understand.

**For Pass standard**, learners will:

- Describe the purpose and importance of each of the tools and techniques commonly used within a software program.

Overall, learner's evidence will be structured logically, although it may be basic in parts and lack technical depth. Their descriptions may be limited in places and contain minor technical inaccuracies.

## Learning aims B and C

For learning aims B and C learners need to provide assessment evidence related to the design, planning, development and testing of a software program that meets the user requirements given to them.

**For Distinction standard**, learners will:

- Produce a fully functional software product that has been tested for usability, functionality and against user requirements.

To fulfil this they will:

- design the software program with an effective and usable user interface, ensuring the user requirements are fully met. They will use suitable interface design software with annotations describing layouts, styles and interactions

- plan and estimate the tasks required to carry out the development and testing of their program, appropriately adjusting their plans due to issues arising and unforeseen delays. They will use a suitable planning tool for software development
- build an efficient software program, from their designs, and make use of procedural, object-orientated and event-driven programming paradigms
- make use of a range of appropriately selected constructs that have been implemented accurately and effectively. The program will be concise and use a range of algorithms to capture, organise and act upon data efficiently and with purpose
- annotate their code consistently and usefully throughout the application, so much so that a third-party developer could continue and improve the software product with ease.

To facilitate the testing of their software they will:

- provide a fully detailed test plan and report, acting upon raised issues where appropriate
- test the software against known, expected cases and fully 'destruction test' the software to find potential pitfalls and unexpected issues
- carry out a full regression test of the software following any unexpected issues, repeating until no further issues are found
- link their test plan and cases back to the user requirements ensuring that the program fully meets the customer's expectations, and justification on areas where features or improvements have been made to usability or functionality.

Overall, the evidence will be easy to read and understand by a third party who may be an experienced or professional software developer. It will be logically structured and use accurate technical software programming terms appropriately.

**For Merit standard**, learners will:

- Produce a functional software product that has been tested for usability, functionality and against user requirements.

To fulfil this they will:

- design the software program with an effective and usable user interface, ensuring the user requirements are met. They will use suitable interface design software with annotations describing layouts, styles and interactions
- plan and estimate the tasks required to carry out the development and testing of their program, making reasonable adjustments due to any delays they experience. They may use a suitable planning tool for software development
- build a software program, from their designs, and make use of most elements of procedural, object-orientated and event-driven programming paradigms
- make use of a range of constructs that have been implemented accurately. The program will be concise and use a range of algorithms to capture, organise and act upon data efficiently and with purpose
- annotate their code usefully throughout the application, so much so that a competent third party could continue and improve the software product.

To facilitate the testing of their software they will:

- provide a fully detailed test plan and report, acting upon raised issues where appropriate
- test the software against known, expected cases and fully ‘destruction test’ the software to find potential pitfalls and unexpected issues
- carry out a full regression test of the software following any unexpected issues, repeating until no further issues are found
- link their test plan and cases back to the user requirements ensuring that the program fully meets the customer’s expectations.

**For Pass standard**, learners will:

- Produce a functional software product that has been tested against user requirements.

To fulfil this they will:

- design an effective software program based on their interpretation of user requirements
- plan and make some estimates of the tasks required to carry out the development and testing of their program
- break down the key tasks required for the development of the program, but may show limited understanding of the tasks required to fully meet the requirement
- create a test plan including test cases that link to the initial user requirements, but may demonstrate a lack of understanding within the depth of testing required to fully ensure the requirements are met
- develop a software program using the procedural programming paradigm, but may involve minor elements of other paradigms, like event-driven and object-orientated, that they feel comfortable with
- implement a selection of programming constructs constructs, generally effectively. They may use a selection of algorithms that help structure the software program
- annotate and comment in their code but may be focused in a few specific areas of the program. Their program structure may have inconsistencies in organisation and/or formatting.

To facilitate the testing of their software they will:

- provide a simple test plan and report, acting upon raised issues where appropriate
- test the software against known, expected cases and briefly ‘destruction test’ the software to find potential pitfalls and unexpected issues
- carry out a regression test of the software following any unexpected issues, repeating until no further issues are found
- link their test plan and cases back to the user requirements, but there may not be any confirmation that the program meets the user requirements.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 25: Computer Numerical Control Programming and Machining
- Unit 26: Robotics.

### Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers to share insights on industrial programming and software development
- staff that work in computing or engineering organisations delivering technical workshops with a focus on the use of industrial computer programming
- contribution of ideas or realistic user requirements for software development projects.

### Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

- Design and development skills related to programming projects that meet user requirements and needs
- Developing and refining a software program, acting upon the results of tests.

# Unit 28: Automated Systems

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will carry out research on automated systems and then design and develop (build, test) a system to solve an engineering-based problem.

## Unit introduction

Automated systems feature heavily in our technological lifestyles. We are surrounded by technology systems that monitor and perform activities on our behalf, from central heating controllers regulating our environment to robots exploring the universe.

The development of automated systems is becoming essential across the world for manufacturing, security systems, home, industrial and transportation systems. Being able to develop and work with automated systems could lead to a challenging, varied and exciting career in any number of various roles in different companies, for example as an electronic engineer and/or software engineer.

In this unit, you will investigate the characteristics, including benefits and features, of existing automated systems. You will design and develop an automated system for a brief. You will develop the system by making progress in small steps and building up programs that can control hardware devices by monitoring sensors and controlling outputs. To do this, you will learn some control programming, hardware assembly and trouble shooting skills.

You will review your final automated system and identify any further improvements.

## Learning aims

In this unit you will:

**A** Understand the characteristics of automated systems used in engineering

**B** Design an automated system to solve an engineering-based problem

**C** Develop an automated system to solve an engineering-based problem.

## Summary of unit

<table>
<tr><th>Learning aim</th><th>Key content areas</th><th>Assessment approach</th></tr>
<tr><td>A Understand the characteristics of automated systems used in engineering</td><td>A1 Use of automated systems<br>A2 Benefits of automated systems<br>A3 Features of automated systems</td><td>Case study of existing automated system.<br>Presentation or report.</td></tr>
<tr><td>B Design an automated system to solve an engineering-based problem</td><td>B1 System specification<br>B2 System architecture<br>B3 Software design</td><td rowspan="2">A design and development portfolio of evidence, including:<br>· client brief and design specification<br>· alternative design options and final choice<br>· system hardware diagram(s)<br>· control software design diagram(s)<br>· a control program specification<br>· audio/visual evidence of the completed system<br>· software listing<br>· test plan and test results<br>· fault repair and optimisation<br>· feedback from the customer or manager.</td></tr>
<tr><td>C Develop an automated system to solve an engineering-based problem</td><td>C1 Hardware development<br>C2 Software development<br>C3 Test, debug and demonstrate automated system</td></tr>
</table>



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# Content

## Learning aim A: Understand the characteristics of automated systems used in engineering

### A1 Use of automated systems

Automated systems including:

- operating in hazardous environments, e.g. satellites in space
- completing monotonous tasks, e.g. food-packaging machinery
- completing precision tasks, e.g. manufacturing engineering components
- monitoring and control, e.g. temperature control system.

### A2 Benefits of automated systems

- Reduced costs.
- Improved performance, e.g. efficiency and effectiveness.
- Customisation, e.g. custom-made engineered parts.
- Improved repeatability (completing the same activity with a high degree of accuracy).
- Improved customer service.

### A3 Features of automated systems

- Hardware devices, including:
  - programmable devices/microcontrollers
  - input devices, e.g. temperature sensors, light-dependent resistors, switches, infrared/ultrasonic sensors, potentiometers, tilt switches
  - output devices, e.g. LEDs, motors, actuators, robotic arms, audio/sound emitters
  - other components, e.g. power source, mechanical structures.
- Control software programs, e.g. code to make a light or LED flash or to operate a line-following robot.

## Learning aim B: Design an automated system to solve an engineering-based problem

### B1 System specification

Design specification e.g. Product Design Specification (PDS) covering:

- intended purpose, performance requirements and 'client'/user requirements (as defined in a customer brief)
- alternative solutions for the intended automated system, e.g. alternative sensor types, hardware configurations and approaches to programming
- constraints, e.g. device capabilities including connectivity and availability, memory storage or programming language
- other requirements e.g. safety, usability, service environment and international standards.

### B2 System architecture

- Specification of least one programmable device, one input and one output device.
- Component and/or device datasheets e.g. for infrared/ultrasonic sensors and motors.
- System hardware connection diagrams showing:
  - overview of the devices to be used
  - the connection/data flow requirements between devices
  - any mechanical structures, e.g. chassis and wheels and the assembly method of devices/components.
- Health and safety issues and precautions, e.g. hardware, electrical connection risks and guidelines, handling equipment.

### B3 Software design

- Description of the main program tasks in terms of input and output.
- Software design using recognised techniques, e.g. structured English, flow charts, pseudocode.
- Connection/interfacing requirements between system components, and to the outside world.
- Predefined code and their sources, e.g. the internet, sensor suppliers.
- Testing of plan and, if appropriate, test data (to test the system inputs and expected outputs).
- Consideration of usability e.g. any user interface requirements for control, programming, starting and stopping, battery charge levels.

## Learning aim C: Develop an automated system to solve an engineering-based problem

### C1 Hardware development

Assembly of hardware, including:

- mechanical structures e.g. protective/aesthetic shell, chassis/framework, axles, wheels
- programmable devices/controllers that can read from input devices (e.g. sensors) and control output devices (e.g. actuators, motors) and store and process data (e.g. Raspberry Pi Pico, Vex, Lego RCX/NXT, Arduino, PIC)
- input devices, e.g. light-dependent resistors, touch sensors, switches, accelerometers, infrared sensors, potentiometers, sound sensors, touch sensors, temperature sensors, tilt sensors
- output devices, e.g. LEDs and LED arrays, lights, motors (e.g. servo and stepper), servo valves, linear actuators, audio/sound emitters (e.g. piezo speakers, buzzers, amplifiers), relays (e.g. H-bridge integrated circuits (ICs) for motor control)
- other components:
  - power source, e.g. photovoltaic cells and batteries
  - data storage, e.g. solid-state storage device.

**C2 Software development**

- Production of original code, using a development environment and editing of predefined program or codes. Suitable languages include: flowchart and 'visual block and text' programming languages e.g. Scratch and Picaxe Blockly.
- Constructs/techniques including:
  - program flow and control e.g.: calling libraries, subroutines/functions, control structure (sequence, selection, iteration – if, else, switch, case, for, do, while, until and end), delays and timing
  - logic and arithmetic e.g.: variables, comparative operators (equal, not equal, less than, more than, less than or equal, more than or equal), Boolean operators (AND, OR, NOT), arithmetic operations (adding, subtracting, multiplication, division, increment, decrement, random).
- Development and refinement of control programs using suitable programming language constructs and techniques.
- Annotation of code to allow effective repair/debugging of the program and for maintainability.

**C3 Test, debug and demonstrate an automated system**

- Simulation (where applicable).
- Testing an automated system for functionality, e.g. against test plan, and if required, test data.
- Formal documentation of test results.
- Document any major changes to the software program and/or hardware.
- Optimisation of the automated system by comparing its performance against the purpose, original requirements and usability, as defined in the customer brief and specification e.g. PDS.
- Demonstrate the final prototype solution to the final customer, considering the difference between in-house testing and customer demonstration (e.g. formal presentation, recording of customer feedback, customer sign-off).

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Understand the characteristics of automated systems used in engineering** | | **A.D1** Evaluate the features of two automated systems used in different engineering applications, explaining the benefits and drawbacks. |
| **A.P1** Outline the features of two automated systems used in different engineering applications, including the main benefits. | **A.M1** Compare the features of two automated systems used in different engineering applications, describing the benefits and drawbacks. | |
| **Learning aim B: Design an automated system to solve an engineering-based problem** | | **BC.D2** Optimise a fully functioning and effective automated system during the design and development process, as demonstrated through the test results, the repair of faults and observation by the customer. |
| **B.P2** Create an adequate hardware connection diagram for the automated system.<br>**B.P3** Create an adequate design for a control program for the automated system. | **B.M2** Create appropriate specification for an automated system, including a hardware connection diagram, a design for a control program and considering alternative solutions. | |
| **Learning aim C: Develop an automated system to solve an engineering-based problem** | | |
| **C.P4** Build a partially functioning automated system containing a programmable device and at least one input device and one output device.<br>**C.P5** Test, during the process, a partially functioning automated system, recording the outcomes of the tests and the actions taken to repair some faults.<br>**C.P6** Demonstrate a partially functioning final automated system to the customer, showing how the system meets the brief. | **C.M3** Develop a functioning automated system that meets a client brief, as demonstrated through the test results, the repair of faults and observation by the customer. | |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aims: B and C (B.P2, B.P3, C.P4, C.P5, C.P6, B.M2, C.M3, BC.D2)

# Further information for teachers and assessors

## Resource requirements

Learners must therefore have access to hardware devices and software development platforms such as:

- a programmable device/microcontroller, e.g. Raspberry Pi, Arduino, PIC, with programming interface and cabling
- a programming environment, e.g. Arduino, PICAXE Programming Editor, Lego NXT Mindstorms environment, Vex
- input devices, e.g. sensors for touch, light, sound, humidity, resistance, temperature, infrared, Hall effect
- output devices, e.g. motors, servos, LEDs, lights, linear actuators
- other components, e.g. mechanical structure, power source, storage media.

For learning aims B and C, solutions involving a robotic arm must **not** be considered as part of the assessment of this unit; however they could be incorporated as part of a larger assessment involving Unit 26: Robotics.

Use of a 'kit of parts' (e.g. Vex Robotics, Lego Mindstorms) is an acceptable approach, as long as the learners show their own design input into how the kit parts are selected and constructed, and how the control software is developed.

Care should be taken not to over-complicate the programming element of this unit, as this needs to be seen as a part of the overall automated system solution, not a topic in its own right. High-level languages, such as C++, would not normally be suitable for this unit, but can be used.

A suitable automated system here may be an autonomous vehicle, which could have one from a number of applications, such as line following or equipment/item retrieval.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Evaluate why two different engineering applications have been automated. They will include:
  - an explanation of the automated process being undertaken for each application, along with the benefits and drawbacks of automation in each situation
  - a block diagram and annotation of each automated system with an explanation of the operating principles, including (as applicable) the programmable device (including programming language), input devices, output devices and user interfaces.
- Use appropriate technical language with accuracy and provide a balanced justification for each application throughout, and a conclusion about why the two applications have been automated.

**For Merit standard**, learners will:

- Compare how two different engineering applications have been automated. They will include:
  - a description of the automated process being undertaken for each application, along with the benefits and drawbacks of automation in each situation
  - a block diagram and annotation of each automated system with a description of the operating principles, including (as applicable) the programmable device (including programming language), input devices, output devices, user interfaces. Any omissions or inaccuracies will be minor.

**For Pass standard**, learners will:

- Outline how two different engineering applications have been automated. They will include:
  - the main benefits of automation in each situation
  - a block diagram of each automated system with an outline of the operating principles, including (as applicable) the programmable device (including programming language), input devices, output devices, user interfaces. This may lack annotation and again there may be some omissions or inaccuracies.

## Learning aims B and C

**For Distinction standard**, learners will:

- Optimise the automated system, during the design and development process, so that it is capable of completing a given operation representative of an industrial scenario effectively.
- Provide a design specification to include:
  - the intended purpose and user requirements (if required)
  - consideration of alternative approaches, and why these have/have not been chosen for development as well as safety, usability, service environment and relevant international standard
  - annotated and fully completed drawings showing: the physical layout of the system and the location, orientation and fixing of any component parts and the hardware connections
  - a detailed software design, showing most elements of the functionality and how these are to be achieved in the control program
  - consideration of efficiency of design and records of any necessary redesign to optimize the solution.
- Realise an effective solution by:
  - building and connecting the hardware elements
  - programming the relevant device(s), using structured programming techniques and annotations in the code
  - completing and resolving basic functionality go/no-go tests. For example, does the system power up, move, respond to commands and does the physical structure retain integrity, present no initial safety hazards.
- Test the solution showing evidence of:
  - a detailed test plan outlining the desired functionality and/or performance against expected outcomes set out in the customer/client brief
  - a record of the actual test results against the detailed plan, which show an optimised and fully functioning automated solution
  - an iterative process of documenting major faults and improving performance, resolving faults and making improvements and re-testing

  - a demonstration of the final solution to a client/customer, showing an optimised automated solution that works effectively, as recorded in the customer's feedback.

**For Merit standard**, learners will:

- Provide an appropriate design specification that should meet the client brief. It will include:
  - the intended purpose and user requirements (if required)
  - consideration of some alternative approaches
  - completed drawings showing: the physical layout of the system and the location, orientation and fixing of any component parts and the hardware connections. Drawings may have minor omissions and some annotation may be missing
  - c software design, showing most elements of the functionality and how these are to be achieved in the control program.
- Realise a functional solution that should meet the client brief by:
  - building and connecting the hardware elements
  - programming the relevant device(s)
  - completing and resolving basic functionality go/no-go tests. For example, does the system power up, move, respond to commands and does the physical structure retain integrity and present no initial safety hazards.
- Test the solution showing evidence of:
  - a test plan outlining the desired functionality and/or performance against expected outcomes from the client brief
  - a record of the actual test results meeting the client brief against the plan
  - resolution of any faults so that the final solution is functional and meets the client brief
  - a demonstration of a functional final solution to a client/customer that meets the client brief.

**For Pass standard**, learners will:

- Provide an adequate design specification to include:
  - the intended purpose and user requirements (if required)
  - completed drawings showing an adequate physical layout of the system and the location of component parts and the hardware connections. Drawings may contain some omissions and there may be some missing annotations
  - an adequate software design, showing the key areas of the functionality and how this is to be achieved in the control program. The design may have some elements of functionality omitted.
- Realise a partially functioning automated system by:
  - building and connecting most hardware elements together
  - programming for at least one device(s) to work with at least one input device and one output device; although there may be some elements of functionality omitted.
- Test an automated system that partially functions, including:
  - a basic test plan outlining some of the expected functionality
  - a record of the actual test results against the plan
  - resolution of some faults, so that the final solution partially functions against the requirements set out in the client/customer brief
  - a demonstration of the partially functioning final solution to a client/customer.

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## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 2: Engineering Thinking Skills to Create Solutions
- Unit 3: Investigating an Engineering Product
- Unit 6: Engineering Materials
- Unit 9: Engineering Design
- Unit 10: Engineering Fitting and Assembly
- Unit 13: Operations and Maintenance of Mechanical Systems and Components
- Unit 23: Electronic Devices and Communication Applications
- Unit 24: Operations and Maintenance of Electrical and Electronic Systems and Components
- Unit 26: Robotics
- Unit 27: General Programming.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, to share insights into automation techniques.
- an overview industry-standard design processes and techniques
- documentation, such as a range of circuit drawings, electrical specifications, data sheets
- setting a customer brief. The unit could be run in conjunction where an employer sets the brief, and is then involved with monitoring accepting the PDS, monitoring hardware and software design, test and implementation. The final demonstration could be to them as a 'client' and their feedback would lead into the Distinction criteria.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting the most appropriate material and techniques and tooling to design and construct an automated system.

### Managing information

- Collecting, recording and interpreting data from various sources.

### Self-management and development

- Development of practical skills relating to hardware construction and software processes will be self-managed by learners.
- Responding to feedback from customer/client/end user and implementing modifications.

# Unit 29: Cyber Security in Engineering

Level: **2**

Unit type: **Internal**

Guided learning hours: **30**

## Unit in brief

Learners will use a range of methods to protect an engineering IT system from cyber security threats and test the protection methods are working.

## Unit introduction

Are you aware of the cyber security threats that engineering IT systems face? Threats can come from many different sources including criminals looking to make money, dissatisfied employees and competitors hoping to steal confidential information.

In this unit you will investigate the threats and protection methods and apply them to a computer system and test they are working.

You will learn about the principles of information security and the variety of threats that systems are exposed to. These include threats from within the engineering organisation and those that are external.

You will develop an understanding of how policies and procedures can be used to help protect systems and you will learn about physical and software-based protection methods.

You will learn about the installation and configuration of protection methods on engineering IT systems and how to test that they are functioning correctly.

## Learning aims

In this unit you will:

**A** Investigate information security and cyber security threats to engineering IT systems

**B** Investigate techniques to protect data and information in engineering IT systems

**C** Implement methods to protect an engineering IT system from security threats.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate information security and cyber security threats to engineering IT systems | **A1** Computer devices and systems<br>**A2** Information security<br>**A3** Cyber security threats | A report providing information on the principles of information security and the types of cyber security threats engineering systems face. |
| **B** Investigate techniques to protect data and information in engineering IT systems | **B1** Vulnerabilities<br>**B2** Policies and procedures<br>**B3** Physical security<br>**B4** Software-based protection | A report providing information on the techniques that can be used to protect systems from security threats. |
| **C** Implement methods to protect an engineering IT system from security threats | **C1** Anti-virus protection<br>**C2** Firewall configuration<br>**C3** Wireless network security<br>**C4** Access control<br>**C5** Back-up<br>**C6** Testing protection applied to an IT system<br>**C7** Engineering IT systems | A practical activity involving the installation, configuration and testing of security measures on a computer system. Assessment evidence will include a logbook with annotated screenshots showing the set up and testing of the security measures. |

# Content

## Learning aim A: Investigate information security and cyber security threats to engineering IT systems

### A1 Computer devices and systems

- A computer is a device/machine, (e.g. a server, microcontroller, programmable logic controller (PLC), laptop/tablet, machines like a Computer Numerical Control machine), or product e.g. a vehicle/car that processes digital data – input–process–output from storage or across a network.
- A system is a collection of at least two computer devices and components that can communicate with each other, e.g. hardware (such as a router, wireless access point or switch), software, peripherals, power supplies, communication links, and input and output devices.

### A2 Information security

- The principles of information security, including:
  - confidentiality
  - integrity
  - availability.
- The need to protect intellectual property from theft or malicious damage, including:
  - confidential organisation-specific information, such as new engineering designs or production techniques
  - trade secrets, such as sensitive engineering research or development data
  - personal information, such as the qualifications and experience of engineering staff.

### A3 Cyber security threats

Types of cyber security threats, including:

- Threats that are internal to the engineering organisation – employee actions, data theft, accidental loss, unintentional disclosure, bring your own device (BYOD) issues, remote worker security, unsafe practices (use of external flash storage, visiting untrusted websites, downloading/uploading files to/from the internet, users overriding security controls).
- Threats that are external to the engineering organisation – data theft, damage or destruction, withholding and/or disruption of IT systems (by competitors, cyber criminals, governments, terrorists) for political purposes or financial gain, such as virus infection, ransomware attacks, denial of service attacks, SQL (Structured Query Language) injection, cloud jacking, email tracking (spy) pixels, fileless attacks.
- Social engineering-based threats, such as phishing, baiting, pretexting.
- Emerging threats, such as deep fakes, synthetic identities, vehicle cyber-attacks, threats to engineered devices, products (e.g. jet engines and vehicles) or systems that are connected to and communicate using the IoT (Internet of Things)/Industry 4.0.

## Learning aim B: Investigate techniques to protect data and information in engineering IT systems

### B1 Vulnerabilities

Protection techniques for an engineering organisation based on policies and procedures, including:

- Application, such as internet and email acceptable use policies, security and password procedures, staff responsibilities, training of staff on IT security issues, disciplinary procedures.
- Management of patches for hardware (firmware) and software (operating systems, security applications).
- Installation of applicable security updates, including rollout management, minimising disruption, sandbox testing of updates and establishing potential risks.

### B2 Policies and procedures

Protection techniques for an engineering organisation based on physical security, including:

- Building and computer/network room security, such as door locks, card key entry, closed circuit television (CCTV), biometrics, keeping IT equipment (server, routers) in a secure location.
- IT disaster recovery plans for use when an engineering organisation's IT system becomes unavailable.
- Back-up procedures, including local (with off-site storage) and cloud-based back-up, full, incremental and differential back-ups.

### B3 Physical security

Protection techniques for an engineering organisation based on physical security, including:

- Building and computer/network room security, such as door locks, card key entry, closed circuit television (CCTV), biometrics, keeping IT equipment (server, routers) in a secure location.
- IT disaster recovery plans for use when an engineering organisation's IT system becomes unavailable.
- Back-up procedures, including local (with off-site storage) and cloud-based back-up, full, incremental and differential back-ups.

### B4 Software-based protection

Protection techniques for an engineering organisation based on software, including:

- Anti-virus software and detection techniques, such as virus signatures and heuristic techniques.
- Software and hardware firewalls and the filtering techniques they use, such as packet filtering, inbound and outbound rules, and network address translation.
- Avoidance of restrictions which might impede normal business operations, such as restrictions on normal network traffic, limitations on remote working, restrictions on data exchange with external systems, identification of legitimate email as spam.
- User authentication, such as user log-on procedures, strong passwords, text and graphical passwords, biometric authentication, multi-factor authentication, one-time passwords (OTP).

- Operating system permissions and the methods they use to restrict users access to resources (user groups and the access rights allocated to them such as folders, files and physical resources such as printers).
- Use of encryption to protect data such as file, folder and whole disk encryption, wireless network encryption, secure transactions using HTTPS and virtual private networks (VPNs).

## Learning aim C: Implement methods to protect an engineering IT system from security threats

Methods, including:

### C1 Anti-virus protection

- Set-up of anti-virus software, configuration of scans and update options.

### C2 Firewall configuration

- Configuration of public and private network settings.
- Inbound and outbound rules to control network connections that are allowed.

### C3 Wireless network security

- Configuration of wireless security settings such as encryption method, SSID settings, MAC address filtering.

### C4 Access control

- Design and implementation of permissions regimes, such as permission settings on files, folders and resources.
- Defining legitimate users and groups, the resources they need to access and the levels of access they need (read, modify, delete).
- Defining password policies, including length, complexity, age and reuse.
- Encryption of folders to protect sensitive information.

### C5 Back-up

- Creating and running a back-up schedule.

### C6 Testing protection applied to an IT system

- Firewall testing to check the firewall allows legitimate traffic through.
- Running anti-virus scans to ensure the system is free of known threats.
- Confirming that permission settings allow and restrict access as required.
- Confirming that operating system updates are being applied.
- Confirming that backed up files can be successfully restored.

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### C7 Engineering IT systems

Systems, including those used for information management and storage related to:

- Research and development.
- Designs, e.g. computer-aided drawings and models.
- Planning, e.g. work-in-progress (WIP), machine capabilities/capacitie.
- Production/manufacture, e.g. additive manufacturing, computer numerical control, microcontroller devices and programmable logic controllers (PLCs).
- Logistics and distribution.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate information security and cyber security threats to engineering IT systems** | | |
| **A.P1** Describe the principles of information security.<br>**A.P2** Describe cyber security threats that can affect an engineering IT system. | **A.M1** Discuss the principles of information security and how different types of cyber security threat can affect an engineering IT system. | **AB.D1** Evaluate the principles of information security and the use of different types of protection techniques to defend the vulnerabilities in an engineering IT system from different cyber security threats. |
| **Learning aim B: Investigate techniques to protect data and information in engineering IT systems** | | |
| **B.P3** Describe how protection techniques can help to defend the vulnerabilities in an engineering IT system from cyber security threats. | **B.M2** Discuss how different types of protection techniques can help to defend the vulnerabilities in an engineering IT system from cyber security threats. | |
| **Learning aim C: Implement methods to protect an engineering IT system from security threats** | | |
| **C.P4** Select routine methods to protect an engineering IT system from cyber security threats.<br>**C.P5** Apply routine methods to protect an engineering IT system from cyber security threats appropriately. | **C.M3** Apply appropriate methods to protect an engineering IT system from cyber security threats, testing the system functions as intended. | **C.D2** Optimise an appropriate range of methods to protect an engineering IT system from cyber security threats, testing the system functions as intended. |

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aim: C (C.P4, C.P5, C.M3, C.D2)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a desktop or laptop computer system with operating system installed
- external USB media for backup files
- anti-virus and firewall software.

### Essential information for assessment decisions

For at least two engineering systems the evidence produced must cover:

- all three principles of information security
- at least three internal, three external and one social engineering threat
- at least two types of policy and procedure, two types of physical security and four types of software protection.

### Learning aims A and B

**For Distinction standard**, learners will:

- Evaluate the effectiveness of the principles of information security giving specific examples. They should explain how confidentiality, integrity and availability apply in an engineering context and show an awareness of the issues involved in implementing them.
- Provide an evaluation of the techniques used to protect engineering systems from cyber security threats considering likely effectiveness of the protection techniques against the different threats and the possible disadvantages the protection methods may have (for example protection methods may slow systems down or make them more difficult to use).
- Provide a conclusion to the evaluation.

**For Merit standard**, learners will:

- Provide a clear explanation and discussion of the principles of information security and how external threats can affect an engineering organisation's IT systems. Learners will show an understanding of how a wide range of different threats can affect systems and data and the likely impact on the engineering system and the organisation.
- Show an understanding of how the protection methods work and the type of threat that they are effective against.

**For Pass standard**, learners will:

- Give descriptions of the principles of information security that will be mostly accurate but may not provide an engineering context or specific examples.
- Give a description of the security threats and the protection methods. This may be basic and lack details and there may be some minor technical inaccuracies or inaccurate use of technical terminology.

### Learning aim C

Learners will need to be provided with an engineering-based scenario which will give them the opportunity to apply both simple (obvious/basic) protection methods and methods which require a degree of configuration such as configuring a firewall and folder permissions.

Simple (basic/obvious) methods of protects must include as a minimum:

- setting up a backup
- setting up an anti-virus scan schedule
- set up of a password policy.

Protection methods required for a merit and above must include as a minimum:

- configurating a firewall to block certain programmes
- configuring permissions to allow different levels of access to different user groups.
- encryption of specific folders.

**For Distinction standard**, learners will:

- Demonstrate that they have applied a range of appropriate protection methods and have optimised the configuration of protection methods to minimise inconvenience to users and/or maximise the protection provided. Typical optimisations may include setting a anti-virus scan schedule to run the virus scan outside office hours, selecting when virus updates are downloaded, selecting specific files or folders to be backed up, setting up a back-up schedule to back up files outside office hours and adjusting the device active hours so updates do not interrupt users while working.
- Learners will also show the optimisations they have applied with screen shots and explain why they are optimal.

**For Merit standard**, learners will:

- Apply a range of protection methods which are appropriate to the scenario.
- Provide a test plan showing how testing of the protection methods was planned and provide evidence to show the outcome of the tests and the action taken if any of the tests failed. If all tests are successful, then no actions are required.

**For Pass standard**, learners will:

- Select routine protection methods appropriate to the engineering IT system scenario provided.
- Provide evidence in the form of screen shots or photographs showing that they have applied the chosen routine protection methods, although some of them may not be fully appropriate to the scenario.

### Links to other units and curriculum subjects

This unit links to, for example:

- Unit 25: Computer Numerical Control Programming and Machining
- Unit 26: Robotics
- Unit 27: General Programming
- Unit 28: Automated Systems.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry who can explain the importance of security and an awareness of cyber security threats and also give an insight into the current and emerging threats that engineering organisations face
- work experience or work shadowing to allow learners to gain first-hand experience of how cyber security issues are delt with in the workplace
- a practical masterclass demonstrating to learners how software protection methods such as Firewalls or access controls can be set up.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Problem solving

- Selecting protection methods and configuring them correctly.

### Self-management and development

- Developing practical skills relating to installation and configuration of protection methods.

# Unit 30: Sustainable Vehicle Power and Structure Design

Level: **2**

Unit type: **Internal**

Guided learning hours: **60**

## Unit in brief

Learners will investigate sustainable vehicle power supply, structure design and safety testing, and design and manufacture vehicle structures.

## Unit introduction

Improved understanding of our impact on the environment has led to more interest in sustainable approaches to travel. The environmental damage caused by petrol and diesel cars and increased fuel costs have encouraged consumers to look towards more environmentally sustainable modes of transport, such as hybrid electric vehicles and zero-emission alternatives, which use an electric motor as a source of power. Vehicle safety and economy continue to improve due to the use of lightweight modern alloys, polymers and composites instead of steel, which has traditionally been the material of choice for the chassis and body.

This unit gives you the opportunity to research and investigate these topics and to apply what you have learnt in practical situations. You will consider low-emission vehicles, focusing on the use of the fuel cells, batteries and electric motors instead of the traditional petrol/diesel engine to understand alternative approaches to environmentally sustainable vehicle design. You will also investigate methods of controlling motor speed and direction.

You will investigate the design of vehicle structures and appropriate materials and manufacturing processes to produce them. You will also learn the importance of rigorous testing by investigating how vehicle safety has improved over time, and you will identify the forces that act on a vehicle during different types of impact and how the vehicle structure can be designed to withstand these forces to protect its occupants.

Finally, you will practically explore alternative approaches to vehicle chassis and body design, working safely and accurately with a range of materials, modelling tools and machines to produce your own vehicle structures.

## Learning aims

In this unit you will:

**A** Examine sustainable vehicle power supply and systems

**B** Explore the principles of vehicle structure design

**C** Explore vehicle safety testing

**D** Design and manufacture a model chassis and body structure.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Examine sustainable vehicle power supply and systems | **A1** Sustainable vehicle power supply<br>**A2** Electric motors and motor control<br>**A3** Electrical energy as a power source | A report that examines approaches to provide sustainable vehicle power supplies, ways in which vehicles can be controlled and ways in which electricity can be generated and stored for use in vehicles. |
| **B** Explore the principles of vehicle structure design | **B1** Vehicle structures<br>**B2** Materials and manufacturing processes | |
| **C** Explore vehicle safety testing | **C1** Impact forces<br>**C2** Impact testing vehicles | A report than includes information about materials and manufacturing processes that are used for producing a range of vehicle structures. The report will also examine design features that protect drivers and passengers from impact forces and how new car assessment programmes are used to improve vehicle safety. |
| **D** Design and manufacture a model chassis and body structure | **D1** Designing and making a vehicle chassis and body structures | A portfolio of evidence including design drawings, annotated photographs, witness statements and a written report that shows the design, development testing and evaluation of a model vehicle chassis and body. |

# Content

## Learning aim A: Examine sustainable vehicle power supply and systems

### A1 Sustainable vehicle power supply

Types, basic operation and benefits of modern vehicle sustainable power supply and systems, including:

- operation overview, to include source of power to move the different types of vehicle (such as cars, vans, trucks, industrial, e.g. forklift, excavator)
  - plug-in electric (EV)
  - hybrid, such as full hybrid (FHEV), mild hybrid, plug-in hybrid
  - fuel cell powered.
- biofuel, electric conversion, liquified petroleum gas (LPG), compressed natural gas and clean diesel for modified conventional vehicles.

### A2 Electric motors and motor control

Traditional methods, alternative methods and advantages/disadvantages of controlling motor speed and direction, including:

- traditional methods, such as mechanical switches and controllers
- alternative methods such as transistors and field effect transistors (FETs), Pulse Width Modulation (PWM) speed control and direction
- advantages/disadvantages to include the use of computer control and software development.

### A3 Electrical energy as a power source

Characteristics, applications and advantages/disadvantages of generating and storing electrical energy for vehicles, including:

- storage such as in batteries (alkaline, lithium ion, lithium polymer, nickel-metal hydride)
- generation such as from hydrogen, fuel cell, solar and wind power
- advantages/disadvantages to include health and safety, impact on carbon footprint, range of travel and economy.

## Learning aim B: Explore the principles of vehicle structure design

### B1 Vehicle structures

Characteristics, applications and construction of vehicle structures, including:

- chassis (separate body and chassis), such as trucks, SUVs, buses, excavators, electric vehicles
- monocoque (combination of chassis and body in 3D structures), such as family cars, vans, racing cars
- space frame (internal tubular cage or frame with non-structural body), such as racing cars, motorcycles, sports cars, kit-cars.

### B2 Materials and manufacturing processes

Identification and properties of appropriate materials and characteristics of manufacturing processes based on their appropriateness for vehicle structures, including:

- materials, e.g. metals, polymers and composites
- material properties, e.g. mechanical, chemical and thermal

- manufacturing processes, e.g. press forming, welding, mechanical fixings, laying-up glass/carbon fibre, casting and injection moulding.

## Learning aim C: Explore vehicle safety testing

### C1 Impact forces

Definition and effects of the following forces that act on a vehicle structure in a collision, and safe vehicle structure/design to withstand them:

- compression force
- tension force
- torsion force
- shear force
- vehicle design and structure such as crumple zone, roll cage, collapsible steering columns and side impact bars.

### C2 Impact testing vehicles

Characteristics of New Car Assessment Programmes (NCAP) methods for impact testing vehicles, including the use of 'crash test dummies' and the data collected, in the following situations:

- frontal impact
- car-to-car side impact
- side pole impact
- rear impact
- proposing modifications and adapting designs.

## Learning aim D: Design and manufacture a model chassis and body structure

### D1 Designing and making a vehicle chassis and body structures

Design and make a model vehicle chassis and body, including the following tasks:

- generation of a range of ideas for appropriate chassis and body structures
- design of a suitable chassis and body through modelling and development
- planning for the manufacture of the chassis and body structure, to include set measurement and tolerances, e.g. set out in a drawing, including wheelbase and tracking
- identification of risks and associated hazards, and possible control measures, to include any environmental impact
- use of tools, materials and manufacturing processes safely and accurately to construct the prototype vehicle chassis and body or an alternative prototype design
- combination of a range of materials and components using different manufacturing processes, aligned to the sustainability of supply
- evaluation of the effectiveness of the model and processes used, giving suggestions for improvements and cost implications.



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## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Examine sustainable vehicle power supply and systems</td><td rowspan="2">A.D1 Evaluate a range of sustainable power supplies and systems and motor control methods for different types of vehicle.</td></tr>
<tr><td>A.P1 Describe the operation of modern vehicle sustainable power supplies and systems.<br>A.P2 Describe how motor speed and direction can be controlled.</td><td>A.M1 Explain the operation and environmental impact of a modern vehicle sustainable power supply and system and how motor speed and direction can be controlled using modern methods.</td></tr>
<tr><td colspan="2">Learning aim B: Explore the principles of vehicle structure design</td><td rowspan="4">BC.D2 Evaluate the use of materials, manufacturing processes, structure design and impact testing methods to ensure the safety of different vehicle structures.</td></tr>
<tr><td>B.P3 Describe the construction of different types of vehicle structure design.<br>B.P4 Describe the properties of materials and characteristics of manufacturing processes used to produce vehicle structures.</td><td>B.M2 Compare different types of vehicle structure design, including the materials and manufacturing processes used.</td></tr>
<tr><td colspan="2">Learning aim C: Explore vehicle safety testing</td></tr>
<tr><td>C.P5 Describe how a vehicle structure can be designed to withstand impact forces.<br>C.P6 Describe a method used for impact testing vehicles.</td><td>C.M3 Explain how a vehicle structure is designed to effectively withstand different types of forces during different types of impact testing methods.</td></tr>
<tr><td colspan="2">Learning aim D: Design and manufacture a model chassis and body structure</td><td rowspan="2">D.D3 Evaluate the developed model vehicle and processes used to make the chassis and body structures.</td></tr>
<tr><td>D.P7 Design a model sustainable chassis and body.<br>D.P8 Safely use processes to produce a model sustainable vehicle chassis and body.</td><td>D.M4 Develop and test a model sustainable vehicle chassis and body.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of three summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aims: B and C (B.P3, B.P4, C.P5, C.P6, B.M2, C.M3, BC.D2)

Learning aim: D (D.P7, D.P8, D.M4, D.D3)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to

- standard high-speed electric vehicle kit of components
- self-assembly vehicle test track
- basic chassis templates
- wide range of materials, components and equipment for vehicle development.

## Essential information for assessment decisions

## Learning aim A

**For Distinction standard**, learners will:

- Evaluate the advantages and disadvantages of at least two sustainable vehicle power supply systems and one approach to modifying a conventional car to make it more sustainable. The evaluation will compare and contrast the characteristics and applications of the systems in terms of their basic operation and benefits.
- Evaluate one method of storing energy and one method of generating electrical energy, including the advantages and disadvantages of each. The evaluation will be balanced and refer to health and safety, range, economy and the impact on the carbon footprint of the vehicles.
- Evaluate one specific method of controlling the speed and direction of vehicles using one traditional control method and one modern alternative method of control. The evaluation will include advantages and disadvantages of each, including the use of computer control and the development of software for controlling motors.

**For Merit standard**, learners will:

- Produce an explanation of one sustainable vehicle power supply system and one approach to modifying a conventional car to make it more sustainable. The explanation will consider the characteristics and applications of the systems and the environmental benefits of each.
- Explain one method of storing energy and one method of generating electrical energy, including the characteristics of each and examples of specific applications. They will include a mostly accurate explanation of how the power source or the energy supply is then converted into the movement of the vehicle, however there might be some omissions.
- Explain one specific method of controlling the speed and direction of vehicles using one traditional control method, such as mechanical switching, and the use of one modern alternative method of control, such as pulse width modulation. The explanations will include advantages and disadvantages of each with respect to controlling motor speed and direction of vehicles.

**For Pass standard**, learners will:

- Produce a description of one sustainable vehicle power supply system, for example a plug-in electric vehicle. The description will also include one approach to modifying a conventional car to make it more sustainable, for example through a conversion to compressed natural gas.

- Describe one method of storing energy, for example the use of lithium-ion batteries, and one method of generating electrical energy such as from a fuel cell. They will describe how the power source or energy supply is then converted into the movement of the vehicle, such as how energy stored in a chemical format in a charged battery is transferred through switching or control arrangements to activate motors for mechanical movement.
- Describe one method of controlling the speed and direction of vehicles using one traditional control method, such as mechanical switching, and one alternative method of control, such as transistors. The description will include details of how both methods are used in the control of vehicles.

### Learning aims B and C

**For Distinction standard**, learners will:

- Evaluate the characteristics of chassis and body, monocoque and space frame structures for specific applications in terms of performance and cost, for example why a monocoque is appropriate for a family saloon car that is sold in large numbers compared to alternatives.
- Evaluate at least two materials in terms of their properties and characteristics of the manufacturing processes used in the construction of each of the three vehicle structures, for example evaluating the advantages and disadvantages of using aluminium for a space frame instead of mild steel.
- Evaluate the effectiveness of specific features of vehicle design used to improve the safety of a vehicle from at least two types of impact, for example the benefits associated with a collapsible steering wheel, or the advantages and disadvantages of side impact bars for side pole impacts.
- Evaluate the use of the data collected during new car assessment programme tests, including methods for collecting data such as that from crash test dummies. The evaluation will consider the advantages and disadvantages of the use of impact test data when modifying and adapting car structure designs to improve the safety of different types of vehicle structure.

**For Merit standard**, learners will:

- Produce an explanation of the characteristics of chassis and body, monocoque and space frame structures and why these types of structure are suitable for specific applications in terms of performance and cost, for example linking the need for a strong heavy duty structure that is provided by a chassis and body to the use of this type of structure for SUVs.
- Explain why the properties of at least two materials used in the construction of each of the three vehicle structures are suitable for the application and also the manufacturing process used to construct the structure of the vehicle, for example the properties of low carbon steel that make it suitable to be pressed to make body panels.
- Explain how specific features of vehicle design are used to improve the safety of a vehicle from at least two types of impact, for example how a crumple zone protects drivers and passengers from frontal impacts.
- Explain how new car assessment programme to judge how vehicle structures withstand forces caused by impacts, for example referring to the use of crash test dummies and how this is used to improve designs.

**For Pass standard**, learners will:

- Produce a description of the characteristics of chassis and body, monocoque and space frame structures. Learners should provide examples of applications of each, for example the use of a monocoque structure for single seat motorsports or space frames for high performance road cars.
- Describe the properties of at least two materials used in the construction of each of the three vehicle structures, for example the use of carbon-fibre composites for a monocoque or aluminium alloys for a space frame. Learners will also describe the manufacturing processes used for the vehicle structures, making connections between the materials and manufacturing processes.
- Describe how vehicle structures can be designed to withstand at least three types of force, such as compression, tension, torsion and shear forces caused by impacts. Learners will include at least two aspects of vehicle design that reduce the effects of impacts, such as roll cages and crumple zones.
- They will also describe one impact test that forms part of the new car assessment programme that is used to judge how vehicle structures withstand forces caused by impacts.

## Learning aim D

For the assessment for Learning aim D learners must have access to a self-assembly vehicle test track, basic chassis templates and a wide range of materials, components, tools and equipment for vehicle chassis and body development.

**For Distinction standard**, learners will:

- Develop a detailed design for a model sustainable vehicle chassis and body. The design will be developed from a range of ideas and incorporate the most suitable aspects of each. They will produce a design that includes accurate and detailed drawings of the chassis and body, with all key dimensions being shown to a suitable level of precision, with tolerances included where necessary.
- Use safe and fully appropriate tools and processes when creating the model chassis and body, for example using the correct size of screwdriver bit for tightening fixings.
- Use appropriate materials, components and fixings to construct the chassis and body, for example using a thermoplastic moulding for the body of the vehicle.
- Check and test the completed vehicle functions as intended, identifying areas of improvement that would improve the performance of the vehicle.
- Demonstrate compliance with safe working practices throughout all of the making and testing activities.

**For Merit standard**, learners will:

- Develop a design for a model sustainable vehicle chassis and body. The design will be developed from a range of ideas that have some variation in approach. They will produce a design that includes drawings of the chassis and body, with most dimensions such as wheelbase and track being included and shown using suitable conventions. The drawing will be mostly accurate and follow drawing conventions.
- Use safe and mostly appropriate tools and processes when creating the model chassis and body, for example using a ring spanner to tighten mechanical fixings instead of an adjustable wrench.

- Use mostly appropriate materials, components and fixings to construct the chassis and body although these might always be the most effective, for example using self-tapping screws where a machine screw and nut might provide a better solution.
- Check and test the completed vehicle functions as intended, identifying aspects that do not perform correctly.
- Demonstrate compliance with safe working practices throughout all of the making and testing activities.

**For Pass standard**, learners will:

- Produce a design for a model sustainable vehicle chassis and body. The design will be based on a range of ideas that show limited variation in approach. They will produce a design that includes drawings of the chassis and body, with key dimensions such as wheelbase and track being given. The drawing will be able to be interpreted but might contain errors and omissions with respect to drawing conventions.
- Use safe, but sometimes inappropriate tools and processes when creating the model chassis and body, for example not centre punching sheet metal before drilling a hole through it.
- Use a range of materials, components and fixings to construct the chassis and body although these might not be the most suitable, for example using low carbon steel square bar when a hollow aluminium box section may be more suitable.
- Check and test the completed vehicle functions as intended.
- Demonstrate compliance with safe working practices throughout all of the making and testing activities.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 31: Vehicle Maintenance Techniques
- Unit 32: Vehicle Engine Technology
- Unit 33: Vehicle Electrical and Electronic Systems.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers from industry, to share insights into sustainable vehicle design and manufacture, the types of power source available and approaches to reduce the carbon footprint of cars
- documentation, such as a range of engineering drawings and associated work instructions for sustainable vehicles
- design challenges and support for the design and making of the model car and body
- work experience, which will allow learners to become familiar with production lines and manufacturing techniques used in the automotive sector.

### Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

#### Problem solving

- Selecting the most appropriate approaches and techniques to complete the design and modelling of a sustainable vehicle chassis and body.

#### Managing information

- Collecting and interpreting information to produce reports.

#### Self-management and development

- Development of practical skills relating to the manufacture of a model car chassis and body, a process that will be self-managed by learners.

# Unit 31: Vehicle Maintenance Techniques

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will select and use technical data, information, equipment, components and materials in order to safely carry out vehicle inspection and maintenance procedures.

## Unit introduction

Have you ever wondered how vehicles are serviced? The aim of this unit is to enable you to select and use appropriate data, information, equipment, components and materials to carry out vehicle inspection and maintenance procedures and to complete maintenance records correctly. This could be anything from checking oil levels or the operation of lights to fitting new parts. You will learn how to replace items such as engine oil, filters and spark plugs and other items that may need replacing according to age and mileage, for example the camshaft belt, anti-freeze or brake fluid.

There are many types of maintenance, such as pre-delivery inspection (conducted before the customer collects the vehicle after purchase or major repair), fixed inspection service and the major service (each of which could be time-based or mileage-based). Regular maintenance is a preventative measure – often breakdowns or major problems arise because early warning signs were not detected.

You will learn about applying the procedures necessary to maintain vehicles (including hybrid/alternative fuel and electric vehicles) and will deal with the principles and practical aspects in a standard manner, so the skills are transferable, regardless of manufacturer or application.

As a vehicle technician, it is important to have knowledge of and to be able to carry out standard vehicle inspection and maintenance procedures, meaning that this unit helps to prepare you for further study or employment in this sector of engineering.

## Learning aims

In this unit you will:

**A** Select data and information for vehicle inspection and maintenance procedures

**B** Select equipment, components and materials for vehicle inspection and maintenance procedures

**C** Safely carry out vehicle inspection and maintenance procedures and complete records.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Select data and information for vehicle inspection and maintenance procedures | **A1** Data and information<br>**A2** Inspection and maintenance procedures for specific vehicles | Computer-based information systems/ vehicle diagnostic systems/ onboard computers/ handheld mobile diagnostics/task sheets/service record sheets should provide information and procedures for the process. This could be used to form a presentation/mini portfolio with comments, digital media, and parts purchase evidence. |
| **B** Select equipment, components and materials for vehicle inspection and maintenance procedures | **B1** Equipment<br>**B2** Components and materials | |
| **C** Safely carry out vehicle inspection and maintenance procedures and complete records | **C1** Inspection methods<br>**C2** Vehicle areas<br>**C3** Maintenance procedures<br>**C4** Inspection and maintenance records | Learner records of completed maintenance tasks validated by signed observation records or witness testimonies. The records should include customer feedback, explanations and justifications for any work completed or additional work needed. The documentation needs to be referenced, clearly showing the assessment decisions made by the assessor. |

## Content

### Learning aim A: Select data and information for vehicle inspection and maintenance procedures

#### A1 Data and information

Find, interpret and use information and data sources for scheduled maintenance procedures, including:

- vehicle technical data and on-board vehicle data and repair processes, such as required service details, tightening torques, pressures, MOT requirements, vehicle specifications
- records of vehicle inspection and customer instructions to show any history for the vehicle or customer aligned to the current vehicle need
- safety and legal requirements, such as PPE, MOT, COSHH, environmental
- schedules of service/inspection and their reasons for use on vehicles, such as by time, by mileage, expected inspection or service areas to be completed
- service data, such as handheld diagnostics, on-board diagnostic displays, on-board service information, manufacturers' and non-manufacturers' workshop manuals, online information, technical service bulletins (TSBs), parts lists, comparison of manual and digital-based sources if available.

Using customer instructions, including:

- typical scenarios, such as breakdown, service, inspection, identified parts replacements, adjustments, modifications.

#### A2 Inspection and maintenance procedures for specific vehicles

Know about inspection and maintenance procedures and their use, including:

- system inspection, such as for serviceability of components
- routine vehicle servicing, such as for basic, fixed and major service
- vehicle breakdown repair, such as for component failure or wear.

### Learning aim B: Select equipment, components and materials for vehicle inspection and maintenance procedures

#### B1 Equipment

Selection and use of hand tools and test instruments specific to each vehicle including for:

- removal and refitting of serviceable items
- brake fluid to test fluid hygroscopicity to ensure no water absorption
- anti-freeze levels to maintain protection of the system
- tension or torque measurements to ensure correct component tightness and belt tensions
- brake efficiency for mandatory vehicle test requirements to ensure maximum safety
- tyre tread depth that could also help identify other areas of potential maintenance
- emissions analysis to maximise economy, minimise environmental impact of harmful gases and identify engine management and emissions component failure
- wheel alignment to maximise tyre life and vehicle performance.

Understanding when the use of specific equipment is appropriate, including:

- cost
- performance
- warranty implications.

### B2 Components and materials

The selection and use of components and materials directly required for the maintenance procedures, including:

- filters, such as air, oil, fuel, pollen systems
- drive belts, such as alternator, power steering, camshaft
- spark plugs
- lubricants, such as brake fluid, antifreeze, oil
- gaskets and seals.

The selection and use of components and materials fitted at the same time if identified as required during inspection, including:

- wiper blades
- brake pads or linings
- light bulbs
- tyres.

Understanding when the use of specific components and materials is appropriate, including:

- cost
- performance
- warranty implications.

## Learning aim C: Safely carry out vehicle inspection and maintenance procedures and complete records

### C1 Inspection methods

The use of methods for completing the required procedures, including:

- how to work safely, avoiding damage to the vehicle, its systems and yourself (including special precautions that may be required when working on hybrid/alternative fuel and electric vehicles), such as using personal protective equipment (PPE), electrical system isolation, use of correct tools/equipment, precautions when working with fuels
- listening to warning systems, on-board diagnostic devices, the running engine as well as the wheels spinning manually
- visually checking lights for damage or security, glass and components for visual damage, signs of corrosion or wear
- checking functioning of lights and components for operation and additional equipment operation such as heating systems, security systems
- measurements to include tyre depth and pressures, anti-freeze content, brake fluid condition, vehicle geometry.

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**C2 Vehicle areas**

Carrying out maintenance procedures and adjustments on vehicle areas, including:

- engine, such as cooling systems, air supply and exhaust systems, fuel systems and ignition systems of vehicle on which you are working (including hybrid vehicles and alternative fuel vehicles)
- transmission, such as clutch operating systems, manual gearboxes, automatic gearboxes, drivelines, and hubs (if appropriate) and final drive assemblies for the type of vehicle on which you are working (including hybrid/alternative fuel and electric vehicles)
- chassis, such as suspension systems, steering systems, braking systems, non-electrical body systems, wheels, and tyres for the type of vehicle on which you are working (including regenerative braking systems and other energy-recuperation systems used on hybrid/electric and alternative fuel vehicles if fitted)
- electrical, such as operation and location of power storage systems (including batteries), power generating systems (including vehicle charging systems), starting systems, lighting systems and ancillary equipment for the type of vehicle on which you are working (including hybrid/alternative fuel and electric vehicles)
- body, such as how to recognise and report cosmetic damage to vehicle components and units outside normal service items.

**C3 Maintenance procedures**

Carrying out the necessary adjustments and replacements, including for:

- malfunction, such as the component or systems not operating as per manufacturers' expectations
- levels, leaks, wear, security, condition, corrosion and serviceability
- damaged components that are either mechanical, body or electrical
- alignment, such as headlamps, body fittings and wheels
- tensions, such as drive belts
- brake adjustments, such as hand brake.

**C4 Inspection and maintenance records**

Use and complete inspection and maintenance records in accordance with manufacturers' or workplace requirements, including:

- vehicle service/inspection documents and service sheets
- manufacturers' documents
- company task card or customer job cards
- resetting vehicle service warning systems using correct processes and equipment.

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Select data and information for vehicle inspection and maintenance procedures</td><td rowspan="4">AB.D1 Justify the need for and use of specific data and information, equipment, components and materials for each stage of a vehicle inspection and maintenance procedure for a specific vehicle.</td></tr>
<tr><td>A.P1 Select appropriate data and information for a vehicle inspection and maintenance procedure.<br>A.P2 Describe a vehicle inspection and maintenance procedure.</td><td>A.M1 Explain each stage of a vehicle inspection and maintenance procedure for a specific vehicle and how appropriate data and information is used.</td></tr>
<tr><td colspan="2">Learning aim B: Select equipment, components and materials for vehicle inspection and maintenance procedures</td></tr>
<tr><td>B.P3 Select appropriate equipment, components and materials for a vehicle inspection and maintenance procedure.</td><td>B.M2 Compare equipment, components and materials that could be used for a vehicle inspection and maintenance procedure for a specific vehicle.</td></tr>
<tr><td colspan="2">Learning aim C: Safely carry out vehicle inspection and maintenance procedures and complete records</td><td rowspan="2">C.D2 Complete a vehicle inspection and maintenance procedure and appropriate vehicle inspection and maintenance records safely, accurately and effectively by refining the process.</td></tr>
<tr><td>C.P4 Carry out a vehicle inspection and maintenance procedure safely.<br>C.P5 Complete appropriate vehicle inspection and maintenance records.</td><td>C.M3 Complete a vehicle inspection and maintenance procedure and appropriate vehicle inspection and maintenance records safely and accurately.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aim: C (C.P4, C.P5, C.M3, C.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- vehicle data, information and records
- resources such as vehicle(s), a workshop and the full range of equipment, maintenance components, materials and appropriate facilities for the disposal of materials.

In addition, access to live workshops to develop learning through observation would be of major benefit.

## Essential information for assessment decisions

For assessment, it is expected that the vehicle(s) being used require maintenance, with problems such as brakes in need of adjustment, bulbs not working, belt tension issues and leaks of some description. Apart from initiating the faults, centres should not prepare the vehicles in any way such as opening the bonnet, removing panels etc. and they should be presented to the learners as if the vehicle had just been driven into the workshop. It is expected that learners will prepare for and undertake a routine vehicle servicing inspection as detailed in the vehicle manufacturers' servicing schedule.

## Learning aims A and B

It is expected that learners will prepare for vehicle inspection and maintenance procedure as detailed in the vehicle manufacturers' servicing schedule.

**For Distinction standard**, learners will:

- Justify the need for an inspection and maintenance procedure for a vehicle, for example reduced efficiency, the frequency of activities due to the mileage and life expectancy of components.
- Justify the equipment they would choose to use in this task, including IT based equipment.
- Supply sufficient depth to understand their reasoning in full.

**For Merit standard**, learners will:

- Explain the process of conducting an inspection and maintenance procedure on a given vehicle. Learners will also explain how appropriate data and information is used to inform the inspection and maintenance tasks. For example, they could explain that the date/mileage of the last oil change would be used to determine if the vehicle needed another oil change at part of the current inspection.
- Make a structured comparison between manufacturer (OEM) supplied components and materials and those available from aftermarket sources. The comparison should focus on cost, performance and warranty impacts.

**For Pass standard**, learners will:

- Select appropriate paper-based and electronic data and information for the set inspection and maintenance procedure.
- Provide information on the maintenance procedures for a given vehicle, which should include both routine vehicle maintenance and vehicle failure repair. The information must be sourced from a range of sources both paper-based and electronic.
- Describe in their own words the inspection and maintenance procedure for the vehicle in their given scenario. The methods discussed should reflect best practice maintenance processes in use in industry.
- Use the given scenario to select the equipment needed to complete the inspection and maintenance procedure.
- Select components and materials that will be needed to complete the inspection and maintenance scenario given. This includes relevant cleaning, lubricating and protection consumables that will aid the maintenance process (spray cleaners, grease, lubricating oil etc).

## Learning aim C

For this learning aim it is expected that learners will conduct the vehicle inspection and maintenance procedure that they planned in learning aims A and B.

**For Distinction standard**, learners will:

- Accurately and effectively complete the required checking/testing, preparation, removing/replacing, adjustment and tidying up inspection and maintenance activities on a vehicle in line with the maintenance information researched in learning aims A and B, and use the best practice processes identified from either paper-based or electronic research.
- Record all the required information on vehicle service/inspection documents and service sheets, manufacturers' documents and company task card or customer job cards, noting all components and systems that required replacement or adjustment and all of your recommendations for components that will need to be replaced soon.
- Carry out the tasks independently and with little involvement from the Assessor. It is also expected that learners take appropriate actions to refine procedures in line with emerging issues during the task. For example, learners will modify the approach taken if a bolt shears or a wire breaks during the replacement of a component.

**For Merit standard**, learners will:

- Accurately and safely complete the required checking/testing, preparation, removing/replacing, adjustment and tidying up inspection and maintenance activities on a vehicle in line with the maintenance information researched in learning aims A and B, and use the best practice processes identified from either paper-based or electronic research.
- Record all the required information on vehicle service/inspection documents and service sheets, manufacturers' documents and company task card or customer job cards, noting all components and systems that required replacement or adjustment.
- Carry out the inspection and maintenance tasks with limited support from the Assessor.

**For Pass standard**, learners will:

- Safely complete the required checking/testing, preparation, removing/replacing, adjustment and tidying up inspection and maintenance activities on a vehicle in line with the maintenance information researched in learning aims A and B.
- Record the required information on vehicle service/inspection documents and service sheets, manufacturers' documents and company task card or customer job cards.
- Carry out the inspection and maintenance tasks with some support from the Assessor.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 1: Working Safely and Effectively in Engineering
- Unit 32: Vehicle Engine Technology
- Unit 33: Vehicle Electrical and Electronic Systems
- Unit 34: Hybrid and Electric Vehicles.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- work placements, so learners can observe different types of vehicle inspection and maintenance procedures for different types of vehicles
- supervision, so that learners on placement can complete different vehicle inspection or maintenance procedures for different types of vehicles
- opportunities for learners to observe the use of advanced vehicle maintenance and diagnostic equipment such as those used in electric vehicle maintenance.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Managing information

- Collecting and using vehicle data.

### Self-management and development

- Development of practical skills relating to inspection and maintenance procedures on vehicles.

### Communication

- Communication skills within a vehicle workshop environment and when dealing with peers and supervisors.

# Unit 32: Vehicle Engine Technology

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will gain an understanding of vehicle petrol and diesel engine construction, operation and components, and the associated systems that support safe starting and running.

## Unit introduction

Since the development of the automobile, the engine has been the consistent provider of power to move the vehicle. The internal combustion engine has evolved in efficiency and design to become the power provider we use in vehicles today. The systems that support and manage the engine have grown in complexity and efficiency throughout this evolution.

This unit will help you to understand the operation of different engine types and designs. You will look at the components within each engine type and the associated systems and how they combine to provide fuel and air for the combustion process in order to generate the energy required to move the car.

You will also learn how the engine can be started using power from the battery and how, once the engine is running, the power used can be replaced by the alternator.

Finally, you will learn the correct methods of removing and refitting a range of engine components and how to test them for serviceability once reinstalled. To do this you will learn safe working practices, how to locate and use data and how to remain safe throughout. It is important at all times to maintain safety, so you will learn about which equipment to use when and how to deal with, for example hazardous fluids and moving components.

## Learning aims

In this unit you will:

**A** Investigate the operating principles of petrol and diesel engines
**B** Investigate vehicle engine fuel, cooling and lubrication systems
**C** Investigate vehicle engine starting and charging systems
**D** Carry out removal and refitting procedures for engine components.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate the operating principles of petrol and diesel engines | **A1** Engine operating principles<br>**A2** Engine construction and components | An illustrated report that includes annotated diagrams, photographs and sketches of the fuel, cooling, lubrication, starting and charging components and systems found in both petrol and diesel engines. The report will detail the operating principles of the systems, how both petrol and diesel engines operate, the differences between them and methods that can be used to ensure both types of engines run efficiently. |
| **B** Investigate vehicle engine fuel, cooling and lubrication systems | **B1** Petrol and diesel fuel systems<br>**B2** Cooling system components and operation<br>**B3** Lubrication system components and operation | |
| **C** Investigate vehicle engine starting and charging systems | **C1** Starting and charging systems<br>**C2** Charging system components and operation<br>**C3** Starting system components and operation | |
| **D** Carry out removal and refitting procedures for engine components | **D1** Safe working practices<br>**D2** Removal and refitting procedures<br>**D3** Correct functioning parameters | A practical activity involving safe working practices, following manufacturers' guidelines, removing and replacing a component from each system. The activity should include component adjustment if applicable. The assessment evidence will include a tutor's report/video/photographic evidence and a learner's record of the operation. |

# Content

## Learning aim A: Investigate the operating principles of petrol and diesel engines

### A1 Engine operating principles

- Common engine four stroke cycle – induction, compression, power and exhaust.
- Cycle application in spark ignition (petrol) and compression ignition (diesel).
- Two stroke operating cycle.

### A2 Engine construction and components

- Engine configurations – inline, flat, vee.
- Components, including engine block, pistons, connecting rods, crankshaft, camshaft, valves.
- Cylinder head design and camshaft configurations (OHC and DOHC).
- Compression ratios.
- Common component failures – gasket faults, poor adjustment, bearing noise.

## Learning aim B: Investigate vehicle engine fuel, cooling and lubrication systems

### B1 Petrol and diesel fuel systems

- Petrol fuel system principles – fuel properties, stoichiometric mixture, combustion processes and exhaust gas chemistry.
- Petrol fuel systems operation:
  - single point, multi point, pressure control, fuel/air mixture management
  - sensor and actuator functions – injectors, fuel pump, filters, throttle position sensor, idle speed control, coolant temperature sensor, map sensor, air temperature sensor, lambda sensor, crankshaft sensor, camshaft sensor.
- Diesel fuel system principles – fuel properties, combustion processes and exhaust gas chemistry.
- Diesel fuel systems operation:
  - direct injection, indirect injection, high pressure direct injection, rotary and inline diesel injection pumps, pressure control, fuel/air mixture management
  - system sensors and actuators – filters, injectors, governors, glow plugs.
- Air intake systems – air system flow, air measurement, temperature, air cooling.
- Safe working practices – system depressurisation, fuel capture and storage, personal protective equipment (PPE).

### B2 Cooling system components and operation

- Engine cooling system operating principles – air cooled, water cooled, system pressurisation.
- Water cooled system components – water pump, thermostat, radiator, header tanks, pressure caps, coolant, cabin heating systems, cooling fans.
- Cooling system failures – leaks, fan system failures, pulley failure, water pump faults.
- Component removal and refitting procedures – fluid removal and replacement, safe working methods, coolant temperature awareness, PPE, coolant collection.

### B3 Lubrication system components and operation

- System function – component lubrication, carbon removal, oxidisation prevention, wear prevention.
- Oil – lubricant types, viscosity, additives, synthetic, semi-synthetic, mineral.
- System components – oil pump, pressure relief valve, pressure warning system, oil coolers, oil filters.
- System operation – wet and dry sump, pressure management, oil distribution, oilways, direct and splash.

## Learning aim C: Investigate vehicle engine starting and charging systems

### C1 Starting and charging systems

- System construction – component identification and purpose, system operation, component location, system wiring and safety devices, wiring diagram.

### C2 Charging system components and operation

- Battery:
  - lead/acid and nickel/cadmium types, location and function, wet and dry cell battery usage
  - construction, cells, plates, separators, electrolyte.
- Charging system components – alternator, drive belt, wiring diagram, cooling fan, AC to DC conversion process.
- Safe working processes – battery disconnection and reconnection precautions, system safety risks, PPE requirements, vehicle system protection.

### C3 Starting system components and operation

- System components – starter motor, ignition control.
- Starter motor – types, construction, components, operating process, over speed protection.

## Learning aim D: Carry out removal and refitting procedures for engine components

### D1 Safe working practices

- How to work safely avoiding damage to the vehicle, its systems and self.
- Specific precautions that may be required when working on fuel and electric systems.
- Personal protective equipment.
- Using specialist protection equipment warning and hazard signs.
- correct tools and equipment as set out in the vehicle repair procedures.
- maintained vehicle lifting and supporting equipment.

### D2 Removal and refitting procedures

- Use of data, manufacturers' procedures, non-manufacturers' data, and previous experience to remove and refit engine components
- Examples of procedures include:
  - oil and filter change
  - spark plug or glow plug change
  - fuel filter change
  - drive belt change
  - replacement of air filters
  - replacement of water pump
  - replacement of battery
  - replacement of cooling system header tank.

### D3 Correct functioning parameters

- Serviceability and testing assessments, such as checking levels, condition, settings, joints and leaks before and after removal and refitting procedures.

## Assessment criteria

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim A: Investigate the operating principles of petrol and diesel engines** | | |
| **A.P1** Identify the engine construction components in petrol and diesel engines.<br>**A.P2** Describe the operating principles of petrol and diesel engines. | **A.M1** Explain the operating differences between petrol and diesel engines. | |
| **Learning aim B: Investigate vehicle engine fuel, cooling and lubrication systems** | | |
| **B.P3** Identify the individual system components within petrol and diesel engine fuel, cooling and lubrication systems.<br>**B.P4** Describe the operation of petrol and diesel engine fuel systems.<br>**B.P5** Describe the operation of petrol and diesel engine cooling and lubrication systems. | **B.M2** Explain the operating differences between petrol and diesel engine fuel systems.<br>**B.M3** Explain the function of each of the main components within petrol and diesel engine cooling and lubrication systems. | **ABC.D1** Evaluate how operating principles and the fuel, cooling, lubrication, starting and charging components and systems combine to start and maintain the efficient running of petrol and diesel engines. |
| **Learning aim C: Investigate vehicle engine starting and charging systems** | | |
| **C.P6** Identify the individual system components within petrol and diesel engine starting and charging systems.<br>**C.P7** Describe the operation of petrol and diesel engine starting and charging systems. | **C.M4** Explain the function of each of the main components within petrol and diesel engine starting and charging systems. | |

| Pass | Merit | Distinction |
|---|---|---|
| **Learning aim D: Carry out removal and refitting procedures for engine components** | | **D.D2** Remove and refit engine components accurately following safe working practices and test to confirm the serviceability of the refitted components. |
| **D.P8** Remove and refit engine components following safe working practices. | **D.M5** Remove and refit engine components accurately following safe working practices. | |

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## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A, B and C (A.P1, A.P2, B.P3, B.P4, B.P5, C.P6, C.P7, A.M1, B.M2, B.M3, C.M4, ABC.D1)

Learning aim: D (D.P8, D.M5, D.D2)

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## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- vehicle and component data including removal and refitting information
- resources such as vehicle(s), a workshop and the full range of equipment, components, materials and appropriate facilities for the disposal of materials.

### Essential information for assessment decisions

### Learning aims A, B and C

**For Distinction standard**, learners will:

- Evaluate the function and operation of components in both a petrol and diesel version of a vehicle engine, including the roles the components play in maintaining an efficient working system.
- Evaluate the efficiency of the four stroke and two stroke cycles used in internal combustion engines. The evaluation will include reasons for differences between the efficiency in operation of petrol and diesel engines.
- Evaluate the operating principles of a petrol engine fuel system and a diesel engine fuel system, including the function of components to ensure the systems run efficiently. The evaluation should also include the cooling, lubrication, engine starting and charging systems, and how these also contribute to the efficient running of both petrol and diesel engines.
- Evaluate how the systems work together when a both a petrol and diesel engine is starting and running, providing details of the expected efficiencies of both types of engine.

**For Merit standard**, learners will:

- Explain the function of components in both a petrol and diesel version of a vehicle engine, including the roles the components play in the working cycles of the engine and how they come together to create a working system.
- Explain the four stroke and two stroke cycles used in internal combustion engines. The explanation will include the differences between the operation of petrol and diesel engines.
- Explain the components of a petrol engine fuel system and a diesel engine fuel system, including how the components work together, typical pressures in the systems and the differences between the two systems.
- Explain the function of components within petrol and diesel engine cooling and lubrication systems. For each, they will explain how the systems operate for both petrol and diesel engines, using technical terminology with accuracy. They should include details of cooling of core components, lubrication of moving parts, sound suppression, prevention of carbon build up and resistance to water contamination.
- Explain the function of components within separate petrol and diesel engine starting and charging systems. They will describe the operation of the systems for both petrol and diesel engines, using some technical terminology with accuracy.

**For Pass standard**, learners will:

- Identify the main functioning components in both a petrol and diesel version of a vehicle engine, defining the roles the components play in the working cycles of the engine and how they come together to create a working system.
- Describe the four stroke and two stroke cycles used in internal combustion engines. The descriptions will include diagrams and technical terms will be used with accuracy.
- Identify the components within separate petrol and diesel fuel, cooling and lubrication systems. For each, they will describe the operation of the systems for both petrol and diesel engines, using some technical terminology with accuracy.
- Identify the components within separate petrol and diesel engine starting and charging systems. They will describe the operation of the systems for both petrol and diesel engines, using some technical terminology with accuracy.

## Learning aim D

For assessment, learners must remove and refit engine components for at least two systems, for example, the fuel system and the lubricating system. Examples of suitable procedures are listed in D2 of the *Content* section. At least one component must be removed and refitted in a petrol engine, and at least one must be removed and refitted in a diesel engine.

**For Distinction standard**, learners will:

- Select and use the most appropriate instructions, tools and equipment for the removal and refitting of engine components from the relevant systems. This might include instructions from a number of sources including the vehicle manufacturer.
- Demonstrate a consistently high level of skill when removing and refitting the components within each system. Tools and equipment will be used safely and correctly, and system components will be refitted with accuracy and meet the working tolerances set by manufacturers. Little, if any, support needed from the Assessor.
- Demonstrate compliance with required safe working practices related to general safety and system specific safe working procedures.
- Test and confirm that both systems are serviceable and operating appropriately following the refitting procedures.

**For Merit standard**, learners will:

- Select and use the most appropriate instructions, tools and equipment for the removal and refitting of engine components from the relevant systems. This might include instructions from a number of sources including the vehicle manufacturer.
- Demonstrate a good level of skill when removing and refitting the components within each system. Tools and equipment will be used safely and correctly, and system components will be refitted with accuracy and meet the working tolerances set by manufacturers. Some support may be needed from the Assessor.
- Demonstrate compliance with required safe working practices related to general safety and system specific safe working procedures.

**For Pass standard**, learners will:

- Identify and use suitable instructions, tools and equipment for the removal and refitting of engine components from the relevant systems.
- Demonstrate some skill when removing and refitting the components within each system. They may sometimes require support from the Assessor to ensure that components are refitted correctly.
- Demonstrate compliance with required safe working practices related to general safety and system specific safe working procedures.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 31: Vehicle Maintenance Techniques
- Unit 33: Vehicle Electrical and Electronic Systems
- Unit 34: Hybrid and Electric Vehicles.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- work placements, so learners can observe a full range of different types of engine component removal and refitting procedures for a large range of vehicles
- supervision, so that learners on placement can carry out a greater range of engine component removal and refitting procedures.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Managing information

- Collecting and using vehicle data.

### Self-management and development

- Development of practical skills relating to inspection and maintenance procedures on vehicles.

### Communication

- Communication skills within a vehicle workshop environment and when dealing with peers and supervisors.

# Unit 33: Vehicle Electrical and Electronic Systems

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will develop their understanding of the electrical and electronic systems involved in vehicle systems, circuits and components.

## Unit introduction

There has been significant development and integration of electrical and electronic systems that benefit almost all areas of life, including the motor vehicle. The functioning and control of almost every system now involves the use of electronic/electrical components making the vehicle safer and more efficient. This includes multi-system cooperation and control. To be able to understand how these systems work, the operating principles must be understood. In this unit, learners will explore the basic electrical/electronic principles that can be applied to vehicle systems, for example light or heavy vehicles, motorsport, motorcycles, etc. This unit explores the nature of electrical current, the factors which influence the flow of electricity and the effects of electrical current flow, and how these can be used to good effect in a motor vehicle. Learners will develop the ability to use formulae to calculate values of electrical voltage, resistance, current and power in electrical/electronic circuits and components. In working through the unit they will identify different types of circuit and the construction of wiring diagrams. There will be an opportunity to use electrical measuring instruments to measure various electrical values and make use of the results to decide if a system is serviceable. The basic characteristics and principles of solid-state electrical components and their use as sensors and actuators is explained and the electronic control of a basic vehicle system using sensors (input) and actuators (output) will be explored.

## Learning aims

In this unit you will:

**A** Investigate the use of measuring instruments and wiring diagrams for vehicle electrical and electronic systems

**B** Understand the principles of solid-state devices used in electrical and electronic circuits and components

**C** Safely conduct electrical and electronic systems tests on vehicles.

## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Investigate the use of measuring instruments and wiring diagrams for vehicle electrical and electronic systems | **A1** Principle of current flow<br>**A2** Electrical values and circuit types<br>**A3** Measuring instruments<br>**A4** Wiring diagrams | A report with diagrams focusing on measuring instruments and wiring diagrams and how these are used. |
| **B** Understand the principles of solid-state devices used in electrical and electronic circuits and components | **B1** Solid-state devices<br>**B2** Electronic control unit (ECU)<br>**B3** Motor vehicle circuits | A report that describes the uses for solid-state devices within systems and circuits, describing the solid-state components and their relationship with the control unit. |
| **C** Safely conduct electrical and electronic systems tests on vehicles | **C1** Safety and safe practice<br>**C2** System and component testing<br>**C3** Types of system tests | A practical activity involving the safe and correct use of testing equipment, to check functionality of vehicle circuits and solid-state devices.<br>The assessment evidence could include data sheets, comparison data and functionality conclusions, reflective job descriptions, assessor observation reports, videos or annotated photographs and witness statements. |

# Content

## Learning aim A: Investigate the use of measuring instruments and wiring diagrams for vehicle electrical and electronic systems

### A1 Principle of current flow

Principles, laws and units linked to electricity and current flow in motor vehicle applications:

- Electron theory, such as flow, electrical charge, conventional current flow.
- Electrical laws, such as Ohm's law, Lenz's law, Kirchhoff's laws, Fleming's rules, Ampere's law.
- Electro motive force (EMF), potential difference (PD), voltage drop (VD).
- Magnetism:
  - effects, permanent and electromagnetism
  - generation of an emf in a conductor, such as relative movement of magnetic field and conductor, varying the magnetic field
  - effect of a magnetic field on an adjacent current carrying conductor.
- Conductors and insulators, such as semi-conductors, conductivity, resistance.
- Electrical units, such as volts, amps, ohms, watts.
- Effect of an electrical current in vehicle components, such as heating, magnetic, chemical.

### A2 Electrical values and circuit types

Common values expected when creating and fault-finding circuits for motor vehicle applications:

- series and parallel circuit calculations, such as voltage, current, resistance, power, use of Ohm's Law and power equations ($V = IR$, $P = IV$, $P = I^2R$)
- types of circuit, such as series, parallel, series/parallel, earth return, insulated return, multiplex
- cable capacity and selection
- circuit protection, such as fuses, circuit breakers, thermal cut outs.

### A3 Measuring instruments

Safe use of measuring instruments for circuit testing in a motor vehicle including:

- digital multimeter, voltmeter, ammeter, oscilloscope, handheld diagnostic equipment
- checking and setting instruments before use, such as correctly specified equipment, free from defects that might affect safety, setting correct scales/ranges
- interpreting results, such as voltage supply from the battery, alternator output current, resistance test to check the condition of an alternator.

### A4 Wiring diagrams

Wiring diagrams that represent simple vehicle systems, including:

- interpretation of standard circuit symbols, such as British Standards Institution (BSI)/International Electrotechnical Commission (IEC) standard symbols
- interpretation of main features of supplied wiring diagrams for a range of vehicles, such as switches, relays, fuses, motors, lamps/lights, earth/ground, battery, fans, horn, radio, instruments.

## Learning aim B: Understand the principles of solid-state devices used in electrical and electronic circuits and components

### B1 Solid-state devices

Solid-state devices and how they work in motor vehicle circuits, including:

- recognition, such as resistor colour coding, component markings and sizes such as 10 kΩ (kiloOhm), 1 μF (micro-Farad), types of construction
- resistors, such as fixed, variable, ballast, rheostat, potentiometer, NTC and PTC resistors
- capacitors, such as capacitance, dielectric materials
- diodes, such as intrinsic and extrinsic semi-conductors, N-type and P-type materials, hole/electron flow, P-N junction characteristics, forward and reverse bias
- transistors, such as operation of NPN and PNP transistors
- sensors
- actuators
- impacts of inputs on outputs.

### B2 Electronic control unit (ECU)

The function of the ECU and the impact of the input and output information:

- for sensors and actuators in providing/receiving signals
- for the processing, such as input–outputs and processing function in an engine management system.

### B3 Motor vehicle circuits

Types, including:

- starter, such as starter motor circuit, ignition circuit
- lighting, such as interior lighting, running lights, head lights, tail lights, reversing lights, stop/brake lights
- indicators, such as turning signals, hazard warning lights
- driver assistance circuits, such as parking sensors, automatic headlamps, automatic windscreen wipers
- instruments, gauges and accessories such as fuel gauge, speedometer, horn, windscreen wipers,

## Learning aim C: Safely conduct electrical and electronic systems tests on vehicles

### C1 Safety and safe practice

Carry out system testing in a safe and structured manner:

- understand and implement safe working practices including PPE, specialist vehicle protective equipment
- define and implement manufacturer recommended testing processes to protect the vehicle systems for damage or accidental activation.

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### C2 System and component testing

Carry out system testing:

- using measuring instruments, such as analogue and digital multimeters, voltmeter, ammeter, oscilloscope, handheld diagnostic equipment
- on a range of basic vehicle electrical systems that contain components such as fuses, switches, variable sensors, batteries, alternators, bulbs
- to collect and collate the results of the tests and to interpret the results to show serviceability and potential failure points
- to recognise the connection between expected and collected results
- to recognise how this data can show component or circuit failures
- using an industry standard format to make component or circuit repair recommendations.

### C3 Types of system tests

Types of tests, including:

- for function, such as lighting (front, rear, brake, indicators), ignition circuit, windscreen wipers, horn
- for performance, such as battery (charge, voltage), alternator (short circuit, grounding, open circuit).

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Investigate the use of measuring instruments and wiring diagrams for vehicle electrical and electronic systems</td><td rowspan="4">AB.D1 Evaluate the use of solid-state devices and the ECU in motor vehicle circuits and how measuring instruments and wiring diagrams can be used to test function and performance.</td></tr>
<tr><td>A.P1 Describe different measuring instruments and their use.<br>A.P2 Interpret the main features of a motor vehicle wiring diagram that complies with drawing standards.</td><td>A.M1 Explain how measuring instruments and wiring diagrams are used to test motor vehicle circuits.</td></tr>
<tr><td colspan="2">Learning aim B: Understand the principles of solid-state devices used in electrical and electronic circuits and components</td></tr>
<tr><td>B.P3 Describe the function of solid-state devices in motor vehicle circuits.<br>B.P4 Describe the function of an ECU in motor vehicle circuits.</td><td>B.M2 Explain the function and operation of a motor vehicle circuit, including the role of the solid-state devices and the ECU.</td></tr>
<tr><td colspan="2">Learning aim C: Safely conduct electrical and electronic systems tests on vehicles</td><td rowspan="2">C.D2 Carry out a series of system tests with accuracy to justify component replacements, using the correct information and instruments in a safe manner.</td></tr>
<tr><td>C.P5 Carry out a series of system tests to obtain results using information and instruments and in a safe manner.</td><td>C.M3 Carry out a series of system tests with accuracy to identify component failures, using information and instruments in a safe manner.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, B.P4, A.M1, B.M2, AB.D1)

Learning aim: C (C.P5, C.M3, C.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- vehicle wiring diagrams, manufacturers' data and repair procedures
- various motor vehicle components, including sensors, actuators and control units
- various circuit and systems test equipment.

In addition, access to live workshop environments to develop learning through observation would be of major benefit.

## Essential information for assessment decisions

## Learning aims A and B

The assessment for these learning aims must allow learners to investigate the use of measuring equipment and the use of solid-state devices and controllers for vehicle electrical and electronic systems.

They must investigate at least three measuring instruments and have access to a wiring diagram containing at least six different features.

They also need to investigate solid state devices including resistors, capacitors, diodes and at least one other type of device as represented in the unit content. Two types of system need to be investigated, one of which must be a lighting circuit.

**For Distinction standard**, learners will:

- Justify the selection and use of measuring instruments for testing vehicle systems, including why other instruments are not suitable.
- Justify the need to refer to wiring diagrams when testing vehicle systems for function and performance.
- Evaluate, using correct technical language, reasons why solid-state devices and the ECU are used in motor vehicle circuits, including how they interact with inputs such as sensors and outputs such as warning lights.

**For Merit standard**, learners will:

- Explain how measuring instruments are used for testing vehicle systems, for example how a multimeter could be used to check for a short circuit in an alternator.
- Explain the reasons for referring to wiring diagrams when testing vehicle systems, for example to check the value of a fuse or expected resistance values.
- Explain how a given motor vehicle circuits function, including details of how the solid-state components and ECU operate when interpreting input signals to operate an output, such as in a parking sensor system.

**For Pass standard**, learners will:

- Describe the operation and use of measuring instruments used for testing motor vehicle systems, for example how a voltmeter could be used to measure the condition of a battery.
- Interpret a given motor vehicle wiring diagram to identify a range of features including switches, lamps, fuses and resistors. The circuit diagram should represent an actual vehicle system.

- Describe how solid-state components, including resistors, capacitors and diodes function when used in motor vehicle circuits. There might be some inaccuracies in the descriptions, however the descriptions will relevant for a vehicle circuit.
- Describe the function of the ECU in motor vehicle circuits. The description might be limited but will be technically accurate and identify the main functions of the ECU.

## Learning aim C

The assessment for this learning aim must allow learners to carry out system tests and fault find. They must carry out at least two system tests. The types of tests must include one functional test and one test for performance as outlined in the unit content.

**For Distinction standard**, learners will:

- Plan the on-vehicle system tests, locating the correct wiring and system information, selecting the most appropriate testing processes and measuring instruments and any system safety processes, e.g. powering down primary or supplementary restraint systems.
- Carry out a range of observed tests on motor vehicle systems that can contain faults, solid state controls or a variety of actuators and sensors in a safe manner. Tests will be conducted with a high level of skill and accuracy and with little, if any, support from the Assessor.
- Justify recommendations for the appropriate repair or replacement of system components. The justification will compare test results with expected values.

**For Merit standard**, learners will:

- Plan the on-vehicle system tests, locating the correct wiring and system information, selecting suitable testing processes and measuring instruments although these might not be the most appropriate for the test being completed.
- Safely carry out a range of observed tests on motor vehicle systems that can contain faults, solid state controls or a variety of actuators and sensors in a safe manner. Testing equipment will be used safely although settings might not always be appropriate, for example using a voltage range of 0-100V rather than a smaller range for testing battery outputs. Any support from the Assessor will be limited.
- Use the outcomes of test results and compare these with expected values to identify components that have failed or need replacing.

**For Pass standard**, learners will:

- Plan the on-vehicle system tests, using relevant wiring and system information, selecting testing processes and measuring instruments that would allow the tests to be completed but may not be fully suitable.
- Safely carry out a range of observed tests on motor vehicle systems that can contain faults, solid state controls or a variety of actuators and sensors. They may sometimes require support from the Assessor to ensure that the correct measurements are being taken.
- Record the outcomes of the tests using appropriate test reports or documentation.

## Links to other units and curriculum subjects

This unit links to, for example:

- Unit 31: Vehicle Maintenance Techniques
- Unit 32: Vehicle Engine Technology
- Unit 34: Hybrid and Electric Vehicles.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- work placements, so learners can observe different types of vehicle and maintenance procedures for different types of vehicles
- supervision, so that learners on placement can complete different vehicle inspection or maintenance procedures for different types of vehicles
- opportunities for learners to observe the use of advanced vehicle maintenance and diagnostic equipment such as those used in electric vehicle maintenance.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Managing information

- Collecting and using vehicle data.

### Self-management and development

- Development of practical skills relating to inspection and maintenance procedures on vehicles.

### Communication

- Communication skills within a vehicle workshop environment and when dealing with peers and supervisors.



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# Unit 34: Hybrid and Electric Vehicles

Level: **2**
Unit type: **Internal**
Guided learning hours: **60**

## Unit in brief

Learners will gain an understanding of hybrid and electric vehicle operation, battery types and charging systems and safe working practices during vehicle maintenance.

## Unit introduction

Our understanding of the changes being caused to the environment by vehicles with internal combustion engines has led to the creation of hybrid and electrical vehicles. With the development of these vehicles comes the challenge of understanding and maintaining new technologies.

Hybrid and electric vehicle operation will be explored in this unit. It is important to understand how the various systems work, how they are laid out and what the components do. This will give learners a working knowledge of the two vehicle types.

These vehicles require batteries and charging systems, and learners will also examine battery characteristics and types, the types of charging systems and the suitability of current charging systems. The use of alternative energy storage systems will also be considered.

Finally, the unit focuses on understanding the safety practices required to safely work with and maintain both hybrid and electric vehicles. This will also cover hazards and the protective equipment needed to conduct any maintenance activity safely.

## Learning aims

In this unit you will:

**A** Examine the operating principles of hybrid vehicles

**B** Examine the operating principles of electric vehicles

**C** Examine hybrid and electric vehicle battery types and charging systems

**D** Investigate hybrid and electric vehicle safe working practices when basic vehicle maintenance is required.

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## Summary of unit

| Learning aim | Key content areas | Assessment approach |
|---|---|---|
| **A** Examine the operating principles of hybrid vehicles | **A1** Identification and component layouts<br>**A2** Operation | A presentation and/or report providing information on hybrid and electric vehicle types, identification, operating layouts together with battery types and charging. |
| **B** Examine the operating principles of electric vehicles | **B1** Identification and component layouts<br>**B2** Operation | |
| **C** Examine hybrid and electric vehicle battery types and charging systems | **C1** Battery characteristics<br>**C2** Types and alternatives<br>**C3** Charging systems | |
| **D** Investigate hybrid and electric vehicle safe working practices when basic vehicle maintenance is required | **D1** Hazard identification<br>**D2** Protective equipment<br>**D3** Safe working practices | A presentation/ report outlining the general/specific risks associated with electric and hybrid vehicle maintenance and repair, the PPE needed to work safely with these vehicles and the safe working process when maintaining these vehicles. |



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# Content

## Learning aim A: Examine the operating principles of hybrid vehicles

### A1 Identification and component layouts

Identification markings used and component positioning:

- identification of hybrid vehicles, such as common names, common symbols, vehicle badge colours, instrument panel symbols and information
- hybrid vehicle classification and functions, such as stop/start, mild hybrid, strong hybrid and plug in hybrid, regeneration, electrical assistance, electric only driving, power socket charging
- component identification – motors, batteries, controllers, dual function gearboxes
- component layout in different configurations such as parallel hybrid (one, two and three clutch systems), series hybrid, power split systems
- motor locations – single motor (front or rear), flywheel, wheel motors
- usage of hybrid technology within a range of vehicles, such as cars, buses, lorries.

### A2 Operation

Hybrid vehicle operation:

- stages of operation – stop/start, start up, acceleration, cruising, deceleration, idle
- phases of operation – power in/power out, kinetic energy recovery system, regeneration systems
- basic operation of each configuration – parallel hybrid (one, two and three clutch systems), series hybrid, power split systems.

## Learning aim B: Examine the operating principles of electric vehicles

### B1 Identification and component layouts

Identification markings used and component positioning:

- electric vehicles, such as common names, common symbols, vehicle badge colours, instrument panel symbols and information
- electric vehicle motor configurations – single motor, wheel motors
- component layout – single motor (front or rear), wheel motors, battery, control units, charger (on-board), isolators, inverter, battery management controller, driver display.

### B2 Operation

Electric vehicle operation:

- component operation – single motor (front or rear), wheel motors, battery, control units, charger (on-board), isolators, inverter, battery management controller, driver display
- usage and operating processes within different types of electric vehicles, such as cars, buses, lorries.

## Learning aim C: Examine hybrid and electric vehicle battery types and charging systems

### C1 Battery characteristics

Range of battery characteristics:

- parameters, such as battery range, battery life cycle, recycling, state of charge, state of health.

### C2 Types and alternatives

The use of:

- battery types, such as lead-acid ($Pb\text{-}PbO_2$), Alkaline (Ni-Cad, Ni-Fe and Ni-MH), Sodium-nickel chloride ($Na\text{-}NiCl_2$), Sodium-sulphur (Na-S), Lithium-ion (Li-ion)
- alternative energy storage systems, such as fuel cells, super capacitors.

### C3 Charging systems

Types and suitability to support hybrid and electric vehicle use:

- charging points – domestic, commercial, wireless power transfer
- charging modes – input types, impacts of inputs, 16A systems, 32A systems, AC charging up to 63A and DC systems.
- required infrastructure – plug types, charging stations, domestic charges, alternative power supplies (solar, wind).

## Learning aim D: Investigate hybrid and electric vehicle safe working practices when basic vehicle maintenance is required

### D1 Hazard identification

Hazards associated with hybrid/electric vehicles:

- Electrical and mechanical hazards, e.g. self-starting hybrid engines, electric shocks, burns, gases, wiring
- High Voltage (HV) and Low Voltage (LV) circuits; identification processes, colour coding, connections, potential hazards
- HV system; de-energising and re-energising, safe handling, isolation.

### D2 Protective equipment

Protective equipment required to protect maintenance personnel:

- workwear, such as protective footwear (rubber soles, non-metallic toe caps), overalls (non-conductive fasteners), gloves (electrical protection), eye protection/goggles, hearing/ear protectors
- floor mats, screens, floor marking tape.

### D3 Safe working practices

- Component identification, e.g. locations, risk, colour coding.
- Correctly identify LV and HV circuits, components within each circuit and their maintenance procedures, e.g. power management, making components safe, correct PPE, de-energizing and re-energising the circuits.
- Accident management, e.g. dealing with shocks, AC shocks, DC shocks, emergency procedures.
- Vehicle maintenance types, e.g. valeting, emergency response, mechanical system maintenance, LV and HV system maintenance.

- Work stages, e.g. Before starting work (isolation, reconnection prevention, verification of power off), during maintenance (insulation, insulated tools), interruptions (de-energised, isolation, key removed, warning signs), completion (remove guards, barriers, damage checks, warning signs removed, re-connect power).

## Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Examine the operating principles of hybrid vehicles</td><td rowspan="6">ABC.D1 Discuss the layout and operation of hybrid and electric vehicles, including battery types, charging systems and the use of alternative energy storage systems.</td></tr>
<tr><td>A.P1 Describe the component layout in one configuration of hybrid vehicle.<br>A.P2 Describe the basic operation of one configuration of hybrid vehicle.</td><td>A.M1 Explain the differences in component layout and basic operation between two configurations of hybrid vehicle.</td></tr>
<tr><td colspan="2">Learning aim B: Examine the operating principles of electric vehicles</td></tr>
<tr><td>B.P3 Describe the component layout of an electric vehicle.<br>B.P4 Describe the basic operation of one type of electric vehicle.</td><td>B.M2 Explain the differences in component layout and basic operation between two types of electric vehicle.</td></tr>
<tr><td colspan="2">Learning aim C: Examine hybrid and electric vehicle battery types and charging systems</td></tr>
<tr><td>C.P5 Describe the characteristics of a battery for a hybrid or electric vehicle.<br>C.P6 Describe a charging system for a hybrid or electric vehicle.<br>C.P7 Describe the operation of an alternative energy storage system for an electric vehicle.</td><td>C.M3 Compare the use of two battery types and two charging systems for a hybrid or electric vehicle.<br>C.M4 Compare the use of two alternative energy storage systems for an electric vehicle.</td></tr>
<tr><td colspan="2">Learning aim D: Investigate hybrid and electric vehicle safe working practices when basic vehicle maintenance is required</td><td rowspan="2">D.D2 Evaluate the differences between maintaining low voltage and high voltage systems on a hybrid or electric vehicle, including the potential hazards, use of protective equipment and the safe working practices required.</td></tr>
<tr><td>D.P8 Describe the potential hazards, protective equipment and safe working practices required when completing maintenance on a hybrid or electric vehicle.</td><td>D.M5 Explain the potential hazards, use of protective equipment and the safe working practices required when completing low voltage and high voltage system maintenance on a hybrid or electric vehicle.</td></tr>
</table>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 Internal assessment* gives information on setting assignments and there is also further information on our website.

There is a maximum number of two summative assignments for this unit.
The relationship of the learning aims and criteria is:

Learning aims: A, B and C (A.P1, A.P2, B.P3, B.P4, C.P5, C.P6, C.P7, A.M1, B.M2, C.M3, C.M4, ABC.D1)

Learning aim: D (D.P8, D.M5, D.D2)

# Further information for teachers and assessors

## Resource requirements

For this unit, learners must have access to:

- information on maintenance procedures for specific hybrid and electric vehicles.

Access to demonstration vehicles or a workplace that maintains hybrid/electric vehicles would enhance the delivery and assessment of this unit.

## Essential information for assessment decisions

## Learning aims A, B and C

For the assessment of these learning aims, learners should be told which types of hybrid and electric vehicles to focus on.

**For Distinction standard,** learners will:

- Produce a comparison between one electric vehicle and one hybrid vehicle, discussing their potential uses and applications, with supporting data and observations.
- Discuss the operating principles of each type of vehicle, its efficiency, and the limitations. Use available data to make informed comments about efficiency measurements and their application in society. Review and comment on the limitations that have been identified for each vehicle type and how these could impact on the users.
- Discuss the use of energy storage systems and the infrastructure needed to support the use and charging of the vehicle types. Include detail on sustainable power, accessibility and charging methods.

**For Merit standard,** learners will:

- Explain two of the hybrid vehicle configurations that are used in road vehicles and the similarities and differences within each configuration. Provide detail on how each configuration operates and the vehicle layouts necessary to make this operation successful.
- Explain two of the electric vehicle types that are used in road vehicles and the similarities and differences within each type. Provide detail on how each type operates and the vehicle layouts necessary to make this operation successful.
- Compare battery types and the characteristics of each, as fitted to hybrid or electric vehicles using manufacturer data. Provide detail on charging processes and efficiencies, the main applications of each battery type and how they function.

**For Pass standard,** learners will:

- Describe the individual vehicle system layouts for hybrid and electric vehicles including the storage and output components within each layout and how they function as part of the system.
- Produce information on how the various components form the operating systems of the hybrid and electric vehicles including the motor systems, power systems and regeneration systems, and how the components work in each system and provide drive, charging and stopping support for the vehicle.

- Describe the general characteristics of the power storage systems used in electric and hybrid vehicles. This includes battery types (acid, alkaline, sodium, lithium-ion, fuel cells and super capacitors), including information on their basic operating processes and the production of electricity.
- Provide information on how charging systems are achieved on the vehicle using several power sources and the infrastructure needed to provide the correct vehicle charging systems. Include the charging options and how these can be used to deliver, for example, direct plug in charging and wireless charging.

## Learning aim D

For the assessment of this learning aim, learners must be provided with details of the hybrid or electric vehicle to focus on and the LV and HV systems within the vehicle. It would be preferable for the vehicle to be one of those considered as part of the assessment for learning aims A, B and C.

**For Distinction standard,** learners will:

- Compare the selection of specific personal protective equipment (PPE) for different maintenance processes used for hybrid or electric vehicles. Specific discussion on the requirements for the PPE related to the hazards that are present. Discussion on how safe working practices are important, related to accident management and different stages of working.

**For Merit standard,** learners will:

- Explain the PPE that will be needed when completing maintenance activities, including why they are needed and how they protect the wearer from hazards on the vehicle. Provide detail on the specific protection required when working on the HV, LV and mechanical components on the hybrid or electric vehicle.

**For Pass standard,** learners will:

- Describe the PPE used when working on a hybrid or electric vehicle including how to use the equipment and how it provides the necessary protection for the user.
- Describe essential safe working practices needed during the maintenance of a hybrid or electric vehicles and some of the hazards this can present.

## Links to other units and curriculum subjects

This unit links to, for example:

Unit 31: Vehicle Maintenance Techniques

Unit 32: Vehicle Engine Technology

Unit 33: Vehicle Electrical and Electronic Systems.

## Employer involvement

This unit would benefit from employer involvement in the form of:

- guest speakers
- staff from hybrid/EV organisations, with expertise in maintenance, to deliver technical workshops
- access to hybrid/EV work areas, enabling learners to see the potential ‘real world’ impact of their new knowledge, understanding and skills.

## Opportunities to develop transferable employability skills

In completing this unit, learners will have the opportunity to develop skills in, for example:

### Managing information

- Recognising important health and safety requirements.

### Self-management and development

- Self-managing the development of knowledge and the writing of reports associated with modern vehicles.

### Problem solving

- Recognising safe and appropriate approaches to carry out maintenance activities.

# 4 Planning your programme

### How do I choose the right BTEC International Level 2 qualification for my learners?

BTEC International Level 2 qualifications come in a range of sizes, each with a specific purpose. You will need to recruit learners very carefully to ensure that they start on the right size of qualification to fit into their study programme and that they take the right pathways or optional units to allow them to progress to the next stage.

Some learners may want to take a number of complementary qualifications or keep their progression options open. These learners may be suited to taking a BTEC International Level 2 Award or Certificate. Learners who then decide to continue with a fuller vocational programme can transfer to a BTEC International Level 2 Extended Certificate or Diploma.

Some learners are sure of the sector in which they wish to work and are aiming for progression into that sector via higher education. These learners should be directed to the two-year BTEC International Level 2 Diploma as the most suitable qualification.

### Is there a learner entry requirement?

As a centre, it is your responsibility to ensure that learners you recruit have a reasonable expectation of success on the programme. There are no formal entry requirements but we expect learners to have sufficient learning to study at this level.

If learners are studying in English we recommend that they have attained at least Level B2 in the Common European Framework of Reference for Languages or Pearson Global Scale of English 51. Please see resources available from Pearson at www.pearson.com/english.

### What is involved in becoming an approved centre?

All centres must be approved before they can offer these qualifications – so that they are ready to assess learners and so that we can provide the support that is needed. Further information is given in *Section 8 Quality assurance*.

### What level of sector knowledge is needed to teach these qualifications?

We do not set any requirements for teachers but recommend that centres assess the overall skills and knowledge of the teaching team to ensure that they are relevant and up to date. This will give learners a rich programme to prepare them for employment in the sector.

### What resources are required to deliver these qualifications?

As part of your centre approval, you will need to show that the necessary material resources and work spaces are available to deliver BTEC International Level 2 qualifications. For some units, specific resources are required.

### How can Pearson Progress help with planning for these qualifications?

Pearson Progress is a digital support system that supports the delivery, assessment and quality assurance of BTECs in centres. It supports teachers with activities such as course creation, creating and verifying assignments and creating assessment plans and recording assessment decisions.

For further information, see *Section 10 Resources and support*.

### Which modes of delivery can be used for these qualifications?

You are free to deliver BTEC International Level 2 qualifications using any form of delivery that meets the needs of your learners. We recommend making use of a wide variety of modes, including direct instruction in classrooms or work environments, investigative and practical work, group and peer work, private study and e-learning.

### What are the recommendations for employer involvement?

BTEC International Level 2 qualifications are vocational qualifications and, as an approved centre, you are encouraged to work with employers on design, delivery and assessment to ensure that it is engaging and relevant, and that it equips learners for progression. There are suggestions in many of the units about how employers could become involved in delivery and/or assessment but these are not intended to be exhaustive and there will be other possibilities at local level.

### What support is available?

We provide a wealth of support materials, including curriculum plans, delivery guides, sample Pearson Set Assignments, Authorised Assignment Briefs and examples of marked learner work.

You will be allocated a Standards Verifier early on in the planning stage to support you with planning your assessments. There will be extensive training programmes as well as support from our Subject Advisor team.

For further details see Section 10 Resources and support.

# 5 Assessment structure

## Introduction

BTEC International Level 2 qualifications are assessed using a combination of *internal assessments*, which are set and marked by teachers, and *Pearson Set Assignments*, which are set by Pearson and marked by teachers.

- Mandatory units have a combination of internal and Pearson Set Assignments.
- Most optional units are externally assessed.

In developing an overall plan for delivery and assessment for the programme, you will need to consider the order in which you deliver units, whether delivery is over short or long periods and when assessment can take place. You must plan the assignments so that learners can demonstrate learning from across their programme.

In administering an internal assignment or a Pearson Set Assignment, the centre needs to be aware of the specific procedures and policies that apply, for example to registration, entries and results. An overview, with signposting to relevant documents, is given in *Section 7 Administrative arrangements*.

## Internal assessment

Our approach to internal assessment for these qualifications will be broadly familiar to experienced centres. It offers flexibility in how and when you assess learners, provided that you meet assessment and quality assurance requirements. You will need to take account of the requirements of the unit format, which we explain in *Section 3 Units*, and the requirements for delivering assessment given in *Section 6 Internal assessment*.

## Pearson Set Assignment units

A summary of the set assignments for this qualification is given in *Section 2 Structure*. You should check this information carefully, together with the details of the unit being assessed, so that you can timetable learning and assessment periods appropriately.

Learners must take the authorised Pearson Set Assignment for the set assignment unit. Teachers are not permitted to create their own assessments for set assignment units. Some assignments may need to be taken in controlled conditions. These are described in each unit.

Please see *Section 6* for resubmission and retaking regulations.

# 6 Internal assessment

This section gives an overview of the key features of internal assessment and how you, as an approved centre, can offer it effectively. The full requirements and operational information are given in the *BTEC International Quality Assurance Handbook*. All members of the assessment team need to refer to this document.

For BTEC International Level 2 qualifications, it is important that you can meet the expectations of stakeholders and the needs of learners by providing a programme that is practical and applied. Centres can tailor programmes to meet local needs and use links with local employers and the wider vocational sector.

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

All units in these qualifications are internally assessed but Pearson sets the assignments for some of the units.

## Principles of internal assessment (applies to all units)

### Assessment through assignments

For all 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 teachers.

An assignment is issued to learners as an assignment brief with a defined start date, a completion date and clear requirements for the evidence that they need to provide. There may be specific observed practical components during the assignment period. Assignments can be divided into tasks and may require several forms of evidence. A valid assignment will enable a clear and formal assessment outcome, based on the assessment criteria. For most units, teachers will set the assignments. For Pearson Set Assignment units, Pearson will set the assignment.

### Assessment decisions through applying unit-based criteria

Assessment decisions for BTEC International Level 2 qualifications are based on the specific criteria given in each unit and set at each grade level. To ensure that standards are consistent in the qualification and across the suite as a whole, the criteria for each unit have been defined according to a framework. The way in which individual units are written provides a balance of assessment of understanding, practical skills and vocational attributes appropriate to the purpose of qualifications.

The assessment criteria for a unit are hierarchical and holistic. For example, if a Merit criterion requires the learner to show 'analysis' and the related Pass criterion requires the learner to 'explain', then to satisfy the Merit 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. In *Appendix 2: Glossary of terms used*, we have set out a definition of terms that assessors need to understand.

Assessors must show how they have reached their decisions using the criteria in the assessment records. When a learner has completed all the assessment for a unit, then the assessment team will give a grade 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 aim
- to achieve a Pass, a learner must have satisfied all the Pass criteria for the learning aims, showing coverage of the unit content and therefore attainment at Level 2 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.

### The assessment team

It is important that there is an effective team for internal assessment. There are three key roles involved in implementing assessment processes in your centre, each with different interrelated responsibilities; the roles are listed below. There is detailed information in the *BTEC International Quality Assurance Handbook*.

- The Lead Internal Verifier (the Lead IV) has overall responsibility for the programme, its assessment and internal verification, record keeping and liaison with the standards verifier, ensuring our requirements are met. The Lead IV acts as an assessor, standardises and supports the rest of the assessment team, making sure that they have the information they need about our assessment requirements and organises training, making use of our standardisation, guidance and support materials.
- Internal Verifiers (IVs) oversee all assessment activities in consultation with the Lead IV. They check that assignments and assessment decisions are valid and that they meet our requirements. IVs will be standardised by working with the Lead IV. Normally, IVs are also assessors but they do not verify their own assessments.
- Assessors set or use assignments to assess learners. Before making any assessment decisions, assessors participate in standardisation activities led by the Lead IV. They work with the Lead IV and IVs to ensure that the assessment is planned and carried out in line with our requirements.

### Effective organisation

Internal assessment needs to be well organised so that the progress of learners can be tracked and so that we can monitor that assessment is being carried out. We support you through, for example, providing training materials and sample documentation. Our online Pearson Progress service can help support you in planning and record keeping. Further information on using Pearson Progress can be found in *Section 10 Resources and support*, and on our website.

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

### Learner preparation

To ensure that you provide effective assessment for your learners, you need to make sure that they understand their responsibilities for assessment and the centre's arrangements.

From induction onwards, you will want to ensure that learners are motivated to work consistently and independently to achieve the requirements of the qualifications. Learners need to understand how assignments are used, the importance of meeting assignment deadlines and that all the work submitted for assessment must be their own.

You will need to give learners a guide that explains how assignments are used for assessment, how assignments relate to the teaching programme and how learners should use and reference source materials, including what would constitute plagiarism. The guide should also set out your approach to operating assessment, such as how learners must submit work and request extensions.

## 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 learner 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 them during the 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:

- to the best of their knowledge 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 can 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. Further information is given in *Section 7 Administrative arrangements*.

### Making assessment decisions using criteria

Assessors make judgements using the criteria. 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 *Essential information for assessment decisions* section in each unit gives examples and definitions related to terms used in the criteria
- the explanation of key terms in *Appendix 2: Glossary of terms used*
- examples of assessed work provided by Pearson
- your Lead IV and assessment team’s collective experience.

Pass and Merit criteria relate to individual learning aims. The Distinction criteria as a whole relate to outstanding evidence across the unit. Therefore, criteria may relate to one learning aim (for example A.D1) or to several learning aims (for example AB.D1). Distinction criteria make sure that learners have shown that they can perform consistently at an outstanding level across the unit and/or that they are able to draw learning together across learning aims.

### 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 IV before it is given to the learner.

## Planning and record keeping

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

The programme must have an assessment plan validated by the Lead IV. When producing a plan, the assessment team needs to consider:

- the time required for training and standardisation of the assessment team
- the time available to undertake teaching and carry out assessment, taking account of when learners may complete assessments and when quality assurance will take place
- the completion dates for different assignments and the name of each Assessor
- who is acting as the Internal Verifier for each assignment and the date by which the assignment needs to be internally verified?

- setting an approach to sampling assessor decisions through internal verification that covers all assignments, assessors and a range of assessment decisions
- how to manage the assessment and verification of learners' work so that they can be given formal decisions promptly
- how resubmission opportunities can be scheduled.

The Lead IV will also maintain records of assessment undertaken. The key records are:

- internal verification of assignment briefs
- learner authentication declarations
- assessor decisions on assignments, with feedback given to learners
- internal verification of assessment decisions
- assessment tracking for the unit.

There are examples of records and further information in the *BTEC International Quality Assurance Handbook*.

## Setting effective assignments (applies to all units without Pearson Set Assignments)

### Setting the number and structure of assignments

This section does not apply to set assignment units. In setting your assignments, you need to work with the structure of assignments shown in the *Essential information for assignments* section of a unit. This shows the structure of the learning aims and criteria that you must follow and the recommended number of assignments that you should use. For these units we provide sample Authorised Assignment Briefs and we give you suggestions on how to create suitable assignments. You can find these materials on our website. In designing your own assignment briefs, you should bear in mind the following points:

- The number of assignments for a unit must not exceed the number shown in *Essential information for assignments*. However, you may choose to combine assignments, for example, to create a single assignment for the whole unit.
- You may also choose to combine all or parts of different units into single assignments, provided that all units and all their associated learning aims are fully addressed in the programme overall. If you choose to take this approach, you need to make sure that learners are fully prepared so that they can provide all the required evidence for assessment and that you are able to track achievement in the records.
- A learning aim 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 aims but the learning aims and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.
- For units containing synoptic assessment, the planned assignments must allow learners to select and apply their learning, using appropriate self-management of tasks.
- You do not have to follow the order of the learning aims of a unit in setting assignments but later learning aims often require learners to apply the content of earlier learning aims and they may require learners 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 aims. 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, through providing challenging and realistic tasks, motivates learners to provide appropriate evidence of what they have learned.

An assignment brief should have:

- a vocational scenario – this could be a simple situation or a full, detailed set of vocational requirements that motivates the learner to apply their learning through the assignment
- 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

BTECs have always allowed for a variety of forms of evidence to be used – provided that they are suited to the type of learning aim 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 you information on what would be suitable forms of evidence to give learners the opportunity to apply a range of employability or transferable skills. Centres may choose to use different suitable forms of evidence to those proposed. Overall, learners should be assessed using varied forms of evidence.

Full definitions of types of assessment are given in *Appendix 2: Glossary of terms used*. These are some of the main types of assessment:

- written reports
- projects
- time-constrained practical assessments with observation records and supporting evidence
- recordings of performance
- 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 aim(s) 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 or to give the group a number of examples that can be used in varied combinations.

## Late completion, resubmission and retakes (applies to all units including Pearson Set Assignment units)

### Dealing with late completion of assignments for internally-assessed units

Learners must have a clear understanding of the centre policy on completing assignments by the deadlines that you give them. Learners may be given authorised extensions for legitimate reasons, such as illness at the time of submission, in line with your 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. Therefore, learners who do not complete assignments by your planned deadline or by the authorised extension deadline may not have the opportunity to subsequently resubmit.

If you accept a late completion by a learner, then the assignment should be assessed normally when it is submitted, using the relevant assessment criteria.

### Resubmission of improved evidence for internally-assessed units

An assignment provides the final assessment for the relevant learning aims and is normally a final assessment decision, except where the Lead IV approves one opportunity to resubmit improved evidence based on the completed assignment brief.

The Lead IV has the responsibility to make sure that resubmission is operated fairly. This means:

- checking that a learner can be reasonably expected to perform better through a second submission, for example, that the learner has not performed as expected
- making sure that giving a further opportunity can be done in such a way that it does not give an unfair advantage over other learners, for example, through the opportunity to take account of feedback given to other learners
- checking that the assessor considers that the learner will be able to provide improved evidence without further guidance and that the original evidence submitted has been authenticated by both the learner and assessor and remains valid.

Once an assessment decision has been given to the learner, the resubmission opportunity must have a deadline within 15 working days after the timely issue of assessment feedback to learners, which is within term time in the same academic year.

A resubmission opportunity must not be provided where learners:

- have not completed the assignment by the deadline without the centre's agreement
- have submitted work that is not authentic.

We recognise that there are circumstances where the resubmission period may fall outside of the 15-day limit owing to a lack of resources being available, for example, where learners may need to access a performance space or have access to specialist equipment. Where it is practical to do so, for example, evaluations, presentations, extended writing, resubmission must remain within the normal 15-day period.

### Retake of internal assessment

A learner who has not achieved the level of performance required to pass the relevant learning aims after resubmission of an assignment may be offered a single retake opportunity using a new assignment. The retake may be achieved at a Pass only.

The Lead Internal Verifier must authorise a retake of an assignment only in exceptional circumstances where they believe it is necessary, appropriate and fair to do so. The retake is not timebound and the assignment can be attempted by the learner on a date agreed between the Lead IV and assessor within the same academic year.

For further information on offering a retake opportunity, you should refer to the *BTEC Centre Guide to Internal Assessment*. Information on writing assignments for retakes is given on our website (www.btec.co.uk/keydocuments).

# 7 Administrative arrangements

## Introduction

This section focuses on the administrative requirements for delivering a BTEC qualification. It is of particular value to Quality Nominees, Lead IVs, Programme Leaders and Examinations Officers.

## Learner registration and entry

Shortly after learners start the programme of learning, you need to make sure that they are registered for the qualification and that appropriate arrangements are made for internal assessment. You need to refer to the *International Information Manual* for information on making registrations for the qualification.

Learners can be formally assessed only for a qualification on which they are registered. If learners' intended qualifications change, for example, if a learner decides to choose a different pathway specialism, then the centre must transfer the learner appropriately.

## Access to assessment

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

Our equality policy requires that all learners should 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 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 for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document *Access Arrangements, Reasonable Adjustments and Special Consideration for General and Vocational Qualifications*.

## Administrative arrangements for assessment

### Records

You 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 the *International Information Manual*. We may ask to audit your records, so they must be retained as specified.

### Reasonable adjustments to assessment

To ensure that learners have fair access to demonstrate the requirements of the assessments, a reasonable adjustment is one that is made before a learner takes an assessment. You are able to make adjustments to internal assessments to take account of the needs of individual learners. In most cases, this can be achieved through a defined time extension or by adjusting the format of evidence. We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. You need to plan for time to make adjustments if necessary.

Further details on how to make adjustments for learners with protected characteristics are given on our website, in the document *Guidance for reasonable adjustments and special consideration in vocational internally assessed units*.

### Special consideration

Special consideration is given after an assessment has taken place for learners who have been affected by adverse circumstances, such as illness. You must operate special consideration in line with our policy (see above). You can give special consideration related to the period of time given for evidence to be provided or for the format of the assessment if it is equally valid. You may not substitute alternative forms of evidence to that required in a unit or omit the application of any assessment criteria to judge attainment. Pearson can consider applications for special consideration if they are in line with the policy.

### Appeals against assessment

Your centre must have a policy for dealing with appeals from learners. These appeals may relate to assessment decisions being incorrect or assessment not being conducted fairly. The first step in such a policy could be a consideration of the evidence by a Lead IV or other member of the programme team. The assessment plan should allow time for potential appeals after assessment decisions have been given to learners. If there is an appeal by a learner, you must document the appeal and its resolution. Learners have a final right of appeal to Pearson but only if the procedures that you have put in place have not been followed. Further details are given in the document *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy*.

## Conducting set assignments

Centres must make arrangements for the secure delivery of Pearson Set Assignments.

At least one Pearson Set Assignment will be available each year for each unit with an additional one provided for resit. Centres must not select an assignment that learners have attempted already.

Each set assignment unit will contain instructions in the *Essential information for assignments* section on how to conduct the assessment of that unit.

Some set assignments will need to be taken with limited controls. Limited controls are described in each unit and may include the following conditions:

- Time: each assignment has a recommended time period. This is for advice only and can be adjusted depending on the needs of learners.
- Supervision: you should be confident of the authenticity of learners' work. This may mean that learners should be supervised.
- Resources: all learners should have access to the same types of resource to complete the assignment.
- Research: learners should be given the opportunity to carry out research outside of the learning context if required for the assignment.

Schools and colleges must be able to confirm that learner evidence is authentic.

## Dealing with malpractice in assessment

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

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 regarding malpractice and advice on preventing malpractice by learners, please see Pearson's *Centre guidance: Dealing with malpractice and maladministration in vocational qualifications*, available on our website.

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 and maladministration in vocational qualifications* document gives comprehensive 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.

### Learner malpractice

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

Learner malpractice in examinations **must** be reported to Pearson using a *JCQ Form M1* (available at www.jcq.org.uk/exams-office/malpractice). The form should be emailed to candidatemalpractice@pearson.com. Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice constitutes staff or centre malpractice.

### Staff/centre malpractice

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

All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ Form M2* (available at www.jcq.org.uk/exams-office/malpractice).

The form, supporting documentation and as much information as possible should be emailed to pqsmalpractice@pearson.com. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More-detailed guidance on malpractice can be found in the latest version of the document *JCQ Suspected Malpractice Policies and Procedures*, available at www.jcq.org.uk/exams-office/malpractice.

### Sanctions and appeals

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

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

- disqualification from the qualification
- being barred 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 you to create an improvement action plan
- requiring staff members to receive further training
- placing temporary blocks on your 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 Heads of Centres (on behalf of learners and/or members of staff) and from individual members (in respect of a decision taken against them personally). Further information on appeals can be found in our document *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy*, which is on our website. In the initial stage of any aspect of malpractice, please notify the Investigations Team by email via pqsmalpractice@pearson.com, who will inform you of the next steps.

## Certification and results

Once a learner has completed all the required components for a qualification, the centre can claim certification for the learner, provided that quality assurance has been successfully completed. For the relevant procedures, please refer to our *International Information Manual*. You can use the information provided on qualification grading to check overall qualification grades.

### Changes to qualification requests

Where a learner who has taken a qualification wants to resit a unit to improve their qualification grade, you firstly need to decline their overall qualification grade. You may decline the grade before the certificate is issued.

## Additional documents to support centre administration

As an approved centre, you must ensure that all staff delivering, assessing and administering the qualifications have access to the following documentation. These documents are reviewed annually and are reissued if updates are required.

- *BTEC International Quality Assurance Handbook*: this sets out how we will carry out quality assurance of standards and how you need to work with us to achieve successful outcomes.
- *International Information Manual*: this gives procedures for registering learners for qualifications, transferring registrations and claiming certificates.
- *Regulatory policies*: our regulatory policies are integral to our approach and explain how we meet internal and regulatory requirements. We review the regulated policies annually to ensure that they remain fit for purpose. Policies related to this qualification include:
    - adjustments for candidates with disabilities and learning difficulties, access arrangements and reasonable adjustments for general and vocational qualifications
    - age of learners
    - centre guidance for dealing with malpractice
    - recognition of prior learning and process.

This list is not exhaustive and a full list of our regulatory policies can be found on our website.

# 8 Quality assurance

## Centre and qualification approval

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

- Centres must have appropriate physical resources (for example equipment, IT, learning materials, teaching rooms) to support the delivery and assessment of the qualification.
- Staff involved in the assessment process must have relevant expertise and/or occupational experience.
- There must be systems in place to ensure continuing professional development for staff delivering the qualification.
- Centres must have in place appropriate health and safety policies relating to the use of equipment by learners.
- Centres must deliver the qualification in accordance with current equality and diversity legislation and/or regulations.
- Centres should refer to the *Further information for teachers and assessors* section in individual units to check for any specific resources required.

## Continuing quality assurance and standards verification

On an annual basis, we produce the *BTEC International Quality Assurance Handbook*. It contains detailed guidance on the quality processes required to underpin robust assessment and internal verification.

The key principles of quality assurance are that:

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

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

The methods we use to do this for BTEC Level 2 include:

- making sure that all centres complete appropriate declarations at the time of approval
- undertaking approval visits to centres
- making sure that centres have effective teams of assessors and verifiers who are trained to undertake assessment
- assessment sampling and verification, through requested samples of assessments, completed assessed learner work and associated documentation
- an overarching review and assessment of a centre's strategy for delivering and quality assuring its BTEC programmes, for example, making sure that synoptic units are placed appropriately in the order of delivery of the programme.

Centres that do not fully address and maintain rigorous approaches to delivering, assessing and quality assurance cannot seek certification for individual programmes or for all BTEC Level 2 programmes. An approved centre must make certification claims only when authorised by us and strictly in accordance with requirements for reporting.

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

# 9 Understanding the qualification grade

## Awarding and reporting for the qualification

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

## Eligibility for an award

In order to be awarded a qualification, a learner must complete all units, AND achieve a Pass or above in all mandatory units unless otherwise specified. Refer to the structure in *Section 2 Structure*.

To achieve any qualification grade, learners must:

- complete and have an outcome (D, M, P or U) for all units within a valid combination
- achieve the **required units at Pass or above** shown in *Section 2*, abiding by the minimum requirements in the compensation table below
- 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. Learners who do not achieve the required minimum grade (P) in units shown in the structure will not achieve a qualification.

Learners who do not achieve sufficient points for a qualification or who do not achieve all the required units may be eligible to achieve a smaller qualification in the same suite, provided they have completed and achieved the correct combination of units and met the appropriate qualification grade points threshold.

## Calculation of the qualification grade

These qualifications are Level 2 qualifications and the certification may show a grade ranging from Level 2 Pass to Level 2 Distinction*. Please refer to the *Calculation of qualification grade* table for the full list of grades. Each individual unit will be awarded a grade of Level 2 Pass, Merit, Distinction. Learners whose level of achievement is below a Level 2 Pass will receive an unclassified (U) for that unit. Distinction* is not available at unit level. Award of Distinction* (D*) D* is an aggregated grade for the qualification, based on the learner's overall performance. In order to achieve this grade, learners will have to demonstrate a strong performance across the qualification as a whole.

To achieve a Level 2 qualification, learners must:

- complete and report an outcome for all units within the permitted combination (NB Unclassified is a permitted unit outcome), and
- achieve the minimum number of points at a grade threshold – see the *Calculation of qualification grade* table with the following allowable tolerances.

| Qualification | Units required at Pass or above | Unit equivalence |
|---|---|---|
| **Award (120 GLH)** | All units must be achieved at Pass or above | 0 units |
| **Certificate (240 GLH)** | All units must be achieved at Pass or above | 0 units |
| **Extended Certificate (360 GLH)** | Mandatory units must be achieved at Pass or above, 60 GLH only at U grade permitted from optional units | e.g. 2´ 30 GLH unit |
| **Diploma (480 GLH)** | Mandatory units must be achieved at Pass or above, 120 GLH only at U grade permitted from optional units | e.g. 4´ 30 GLH units<br>OR<br>2´ 60 GLH unit |

### Points available for unit size and grades

The table below shows the **number of points scored per 10 guided learning hours** at each grade.

| Points per grade per 10 Guided Learning Hours | | | |
|---|---|---|---|
| **Unclassified** | **Level 2 Pass (P)** | **Level 2 Merit (M)** | **Level 2 Distinction (D)** |
| 0 | 4 | 6 | 8 |

We will automatically calculate the qualification grade for your learners when your learner unit grades are submitted. Learners will be awarded qualification grades for achieving the sufficient number of points within the ranges shown in the *Calculation of qualification grade* table.

Example

A learner achieves a Level 2 Pass grade for a unit. The unit size is 30 guided learning hours (GLH). Therefore, they gain 12 points for that unit, i.e. 4 points for each 10 GLH, so 12 points for 30 GLH.

## Calculation of qualification grade

| Award | | Certificate | | Extended Certificate | | Diploma | |
|---|---|---|---|---|---|---|---|
| 120 GLH | | 240 GLH | | 360 GLH | | 480 GLH | |
| Grade | Points threshold | Grade | Points threshold | Grade | Points threshold | Grade | Points threshold |
| U | 0 | U | 0 | U | 0 | U | 0 |
| Level 2 Pass | 48 | Level 2 PP | 96 | Level 2 PP | 144 | Level 2 PP | 192 |
| | | Level 2 MP | 114 | Level 2 MP | 174 | Level 2 MP | 234 |
| Level 2 Merit | 66 | Level 2 MM | 132 | Level 2 MM | 204 | Level 2 MM | 276 |
| | | Level 2 DM | 150 | Level 2 DM | 234 | Level 2 DM | 318 |
| Level 2 Distinction | 84 | Level 2 DD | 168 | Level 2 DD | 264 | Level 2 DD | 360 |
| | | Level 2 D*D | 174 | Level 2 D*D | 270 | Level 2 D*D | 366 |
| Level 2 Distinction* | 90 | Level 2 D*D* | 180 | Level 2 D*D* | 276 | Level 2 D*D* | 372 |

This table shows the minimum thresholds for calculating grades. The table will be kept under review over the lifetime of the qualification. The most up to date table will be issued on our website.

Pearson will monitor the qualification standard and reserves the right to make appropriate adjustments.

The tables below give examples of how the overall grade is determined.

Examples used are for illustrative purposes only. Other unit combinations are possible, see *Section 2 Structure*.

**Example 1**

Achievement of a Certificate with a Level 2 MM grade

| | GLH | Weighting (GLH/10) | Grade | Grade points | Points per unit (weighting × grade points) |
|---|---|---|---|---|---|
| Unit 1 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 2 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 3 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 4 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 5 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 6 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 7 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| **Qualification grade totals** | **240** | **24** | **Level 2 MM** | | **144** |

The learner has sufficient points for a Level 2 MM grade.

**Example 2**

Achievement of a Certificate with a Level 2 D*D grade

| | GLH | Weighting (GLH/10) | Grade | Grade points | Points per unit (weighting × grade points) |
|---|---|---|---|---|---|
| Unit 1 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 2 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 3 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 4 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 5 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 6 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 7 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| **Qualification grade totals** | **240** | **24** | **Level 2 D*D** | | **174** |

The learner has sufficient points for a Level 2 D*D grade.

**Example 3**

Achievement of an Extended Certificate with a Level 2 MP grade

| | GLH | Weighting (GLH/10) | Grade | Grade points | Points per unit (weighting × grade points) |
|---|---|---|---|---|---|
| Unit 1 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 2 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 3 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 4 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 5 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 6 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 7 | 60 | 6 | Level 2 Pass | 4 | 24 |
| Unit 10 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 12 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 14 | 60 | 6 | Level 2 Pass | 4 | 24 |
| **Qualification grade totals** | **360** | **36** | **Level 2 MP** | | **180** |

The learner has sufficient points for a Level 2 MP grade.

**Example 4**

Achievement of a Diploma with a Level 2 MM grade

| | GLH | Weighting (GLH/10) | Grade | Grade points | Points per unit (weighting × grade points) |
|---|---|---|---|---|---|
| Unit 1 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 2 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 18 | 60 | 6 | Level 2 Merit | 6 | 36 |
| Unit 3 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 5 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 18 | 30 | 3 | Level 2 Pass | 4 | 12 |
| Unit 19 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| Unit 23 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| Unit 4 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 24 | 60 | 6 | Level 2 Pass | 4 | 24 |
| Unit 25 | 60 | 6 | Level 2 Pass | 4 | 24 |
| **Qualification grade totals** | **480** | **48** | **Level 2 MM** | | **276** |

The learner has sufficient points for a Level 2 MM grade.

**Example 5**

Achievement of a Diploma with a Level 2 DD grade

| | GLH | Weighting (GLH/10) | Grade | Grade points | Points per unit (weighting × grade points) |
|---|---|---|---|---|---|
| Unit 1 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 2 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 30 | 60 | 6 | Level 2 Merit | 6 | 36 |
| Unit 3 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 5 | 30 | 3 | Level 2 Merit | 6 | 18 |
| Unit 4 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 19 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| Unit 23 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| Unit 18 | 30 | 3 | Level 2 Distinction | 8 | 24 |
| Unit 25 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| Unit 27 | 60 | 6 | Level 2 Distinction | 8 | 48 |
| **Qualification grade totals** | **480** | **48** | **Level 2 DD** | | **360** |

The learner has sufficient points for a Level 2 DD grade.

# 10 Resources and support

Our aim is to give you a wealth of resources and support to enable you to deliver BTEC International Level 2 qualifications with confidence. You will find a list of resources to support teaching and learning, and professional development on our website.

## Support for setting up your course and preparing to teach

### Specification

The specification (for teaching from September 2022) gives you details of the administration of the qualifications and information on the units for the qualifications.

## Pearson Progress

Pearson Progress is a digital support system that helps you to manage the assessment and quality assurance of the Pearson BTEC International Level 2 Engineering qualifications. It supports delivery, assessment and quality assurance of BTECs in centres and supports teachers and students as follows:

- course creation
- creating and verifying assignments
- creating assessment plans and recording assessment decisions
- upload of assignment evidence
- tracking progress of every learner.

The system is accessible for teachers and learners so that both teachers and learners can track their progress.

## Support for teaching and learning

Pearson Learning Services provides a range of engaging resources to support BTEC International Level 2 qualifications, these may include:

- delivery guides, which give you important advice on how to choose the right course for your learners and how to ensure you are fully prepared to deliver the course. They explain the key features of the BTEC International Level 2 Engineering qualifications, for example employer involvement and employability skills. They also cover guidance on assessment and quality assurance. sample schemes of work are provided for each mandatory unit as well as a selection of optional units. These are available in Word™ format for ease of customisation
- slide presentations for use in your teaching to outline the key concepts of a unit
- delivery plans that help you structure delivery of a qualification.

We also provide paid for resources and courseware which may include:

- teacher resource packs developed by Pearson including materials and activities to fully support your teaching of units
- student books, designed to support the teaching and learning journey. These include case studies, discussion prompts, key content and supporting images to help learners develop their understanding. Items from the student books will link with other resources, which will support teaching and learning.

## Support for assessment

### Sample assessment materials for internally-assessed units

For internal units assessed with a Pearson Set Assignment we will provide a sample assignment as an example of the form of assessment for the unit. For the remaining internally set units, we allow you to set your own assignments, according to your learners' preferences and to link with your local employment profile.

We provide a service in the form of Authorised Assignment Briefs and sample Pearson Set Assignments, which are approved by Pearson Standards Verifiers. They are available via our website.

## Pearson English

Pearson provides a full range of support for English learning including diagnostics, qualifications and learning resources. Please see www.pearson.com/english

## Training and support from Pearson

### People to talk to

There are many people available to support you and give you advice and guidance on delivery of your BTEC International Level 2 qualifications. They include the following.

- Subject Advisors – available for all sectors. They understand all Pearson qualifications in their sector and can answer sector-specific queries on planning, teaching, learning and assessment.
- Standards Verifiers – they can support you with preparing your assignments, ensuring that your assessment plan is set up correctly, and support you in preparing learner work and providing quality assurance through sampling.
- Regional teams – they are regionally based and have a full overview of the BTEC qualifications and of the support and resources that Pearson provides. Regions often run network events.
- Customer Services – the 'Support for You' section of our website gives the different ways in which you can contact us for general queries. For specific queries, our service operators can direct you to the relevant person or department.

### Training and professional development

Pearson provides a range of training and professional development events to support the introduction, delivery, assessment and administration of BTEC International Level 2 qualifications. These sector-specific events, developed and delivered by specialists, are available both face to face and online.

#### 'Getting Ready to Teach'

These events are designed to get teachers ready for delivery of the BTEC International Level 2 qualifications. They include an overview of qualification structures, planning and preparation for internal assessment, and quality assurance.

### Teaching and learning

Beyond the 'Getting Ready to Teach' professional development events, there are opportunities for teachers to attend sector- and role-specific events. These events are designed to connect practice to theory; they provide teacher support and networking opportunities with delivery, learning and assessment methodology.

Details of our training and professional development programme can be found on our website.

# Appendix 1: Transferable employability skills

## The need for transferable skills

In recent years, higher-education institutions and employers have consistently flagged the need for learners to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work.

The Organisation for Economic Co-operation and Development (OECD) defines skills, or competencies, as 'the bundle of knowledge, attributes and capacities that can be learned and that enable individuals to successfully and consistently perform an activity or task and can be built upon and extended through learning'. [1]

To support the design of our qualifications, the Pearson Research Team selected and evaluated seven global 21st-century skills frameworks. Following on from this process, we identified the National Research Council's (NRC) framework [2] as the most evidence-based and robust skills framework, and have used this as a basis for our adapted skills framework.

The framework includes cognitive, intrapersonal skills and interpersonal skills.

The NRC framework is included alongside literacy and numeracy skills.


The skills have been interpreted for this specification to ensure that they are appropriate for the subject. All of the skills listed are evident or accessible in the teaching, learning and/or assessment of the qualifications. Some skills are directly assessed. Pearson materials will support you in identifying these skills and in developing these skills in learners.

The table overleaf sets out the framework and gives an indication of the skills that can be found in engineering, it indicates the interpretation of the skills in this area. A full interpretation of each skill, with mapping to show opportunities for learner development, is given on the subject pages of our website: http://qualifications.pearson.com.

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[1] OECD – *Better Skills, Better Jobs, Better Lives* (OECD Publishing, 2012)

[2] Koenig, J. A. (2011) *Assessing 21st Century Skills: Summary of a Workshop* (National Academies Press, 2011)

| | | |
|---|---|---|
| **Cognitive skills** | Cognitive processes and strategies | Critical thinking<br>Problem solving<br>Analysis<br>Reasoning/argumentation<br>Interpretation<br>Decision making<br>Adaptive learning<br>Executive function |
| | Creativity | Creativity<br>Innovation |
| **Intrapersonal skills** | Intellectual openness | Adaptability<br>Personal and social responsibility<br>Continuous learning<br>Intellectual interest and curiosity |
| | Work ethic/ conscientiousness | Initiative<br>Self-direction<br>Responsibility<br>Perseverance<br>Productivity<br>Self-regulation (metacognition, forethought, reflection)<br>Ethics<br>Integrity |
| | Positive core self-evaluation | Self-monitoring/ self-evaluation/ self-reinforcement |
| **Interpersonal skills** | Teamwork and collaboration | Communication<br>Collaboration<br>Teamwork<br>Cooperation<br>Empathy/perspective taking<br>Negotiation |
| | Leadership | Responsibility<br>Assertive communication<br>Self-presentation |

Developing the ability to make a persuasive case in the fields of mechatronics or vehicle technology and new technologies, supporting one or more arguments, including the ability to create a balanced and evaluated argument.

Taking responsibility for finding and correcting errors in coding and algorithms.

Advocating the position of another in an oral presentation.

# Appendix 2: Glossary of terms used

This is a summary of the key terms used to define the requirements in the units.

| Term | Definition |
|---|---|
| Analyse/Study | Learners present the outcome of methodical and detailed examination, either:<br>· breaking down a theme, topic or situation in order to interpret and study the interrelationships between the parts<br>and/or<br>· information or data to interpret and study key trends and interrelationships.<br>Analysis can be through performance, practice, written or, less commonly, verbal presentation. |
| Assemble/Build/Construct/Devise/Design/Plan | Related to use and demonstration of practical equipment/techniques/ procedures. |
| Assess | Learners present a careful consideration of varied factors or events that apply to a specific situation or to identify those which are the most important or relevant and arrive at a conclusion. |
| Calculate | Learners manipulate quantitative data to help analyse and compare findings. |
| Classify | Learners arrange engineering information in categories according to shared qualities or characteristics. |
| Compare | Learners identify the main factors relating to two or more items/ situations or aspects of a subject that is extended to explain the similarities, differences, advantages and disadvantages. |
| Demonstrate | Learners give a practical exhibition and explanation of how a engineering skill is performed. |

| Term | Definition |
|---|---|
| Describe | Learner work gives a clear, objective account in their own words showing recall and, in some cases, application of the relevant features and information about a subject. |
| Determine | Use of this verb normally requires breadth of content coverage. |
| Develop | Learners create and build in familiar engineering contexts. |
| Examine | Learners are expected to select and apply knowledge to less familiar contexts. |
| Explain | Learner work shows clear details and gives reasons and/or evidence to support an opinion, view or argument. It could show how conclusions are drawn. |
| Explore | Learners look at different aspects to expand their knowledge. |
| Identify | Usually requires some key information to be selected from a given stimulus/resource. |
| Interpret | Learners scrutinise engineering data/information to come to a conclusion. |
| Investigate | Learner work tests the following through practical exploration:<br>· qualities of materials<br>· techniques<br>· processes or contexts. |
| Justify | Learners give reasons or evidence to:<br>· support an opinion<br>· prove something right or reasonable. |
| Measure | To determine the dimensions or angle from a diagram using an instrument such as a ruler or protractor. |
| Outline | Learners give a summary of different points in relation to an area of content. |

| Term | Definition |
| --- | --- |
| Present | When learners show their engineering information/observation(s) in an appropriate way. |
| Process | Learners perform a series of actions. |
| Produce | When learners are required to create/ make/establish. |
| Record | When learners evidence their scientific observations/raw data. |
| State | Requires recall of one or more pieces of information. |

This is a key summary of the types of evidence used for BTEC International Level 2 qualifications.

| Type of evidence | Definition and purpose |
| --- | --- |
| Case study | A specific example to which all learners must select and apply knowledge. Used to show application to a realistic context where direct experience cannot be gained. |
| Portfolio of evidence | A written and/or audio/visual record of competence against assessment criteria. |
| Individual project | A self-directed, large-scale activity requiring planning, research, exploration, outcome and review. Used to show self-management, project management and/or deep learning, including synopticity. |
| Development log | A record kept by the learner to show the process of development. Used to show method, self-management and skill development. |

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