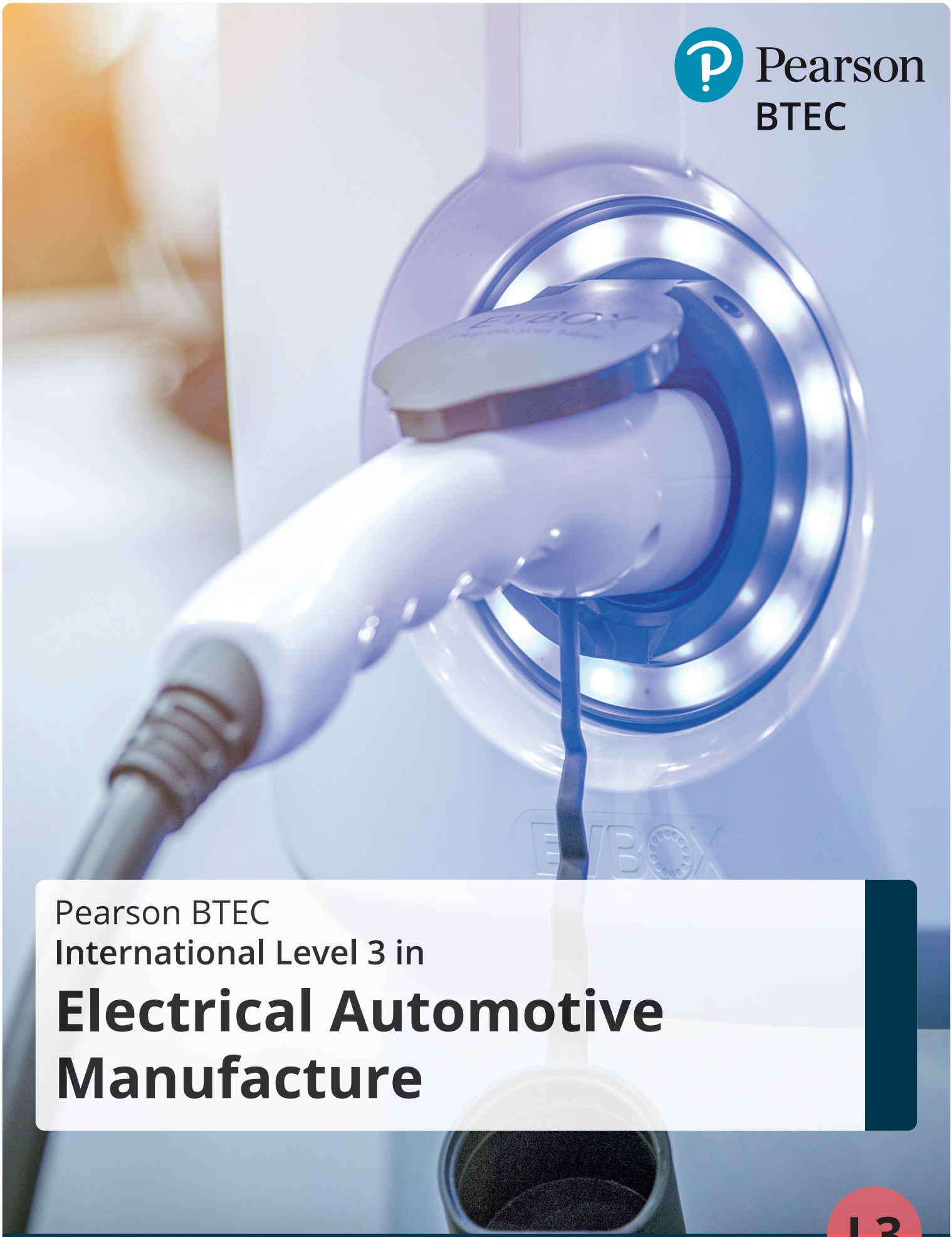

Pearson BTEC

Pearson BTEC
International Level 3 in

Electrical Automotive Manufacture

L3

Specification

First teaching from January 2022

Issue 2

Pearson BTEC International Level 3 Qualifications in Electrical Automotive Manufacture

Specification

First teaching January 2022

Issue 2

About Pearson

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

This specification is Issue 2. We will inform centres of any changes to this issue. The latest issue can be found on our website.

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

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Welcome

With a track record built over 40 years of learner success, our BTEC International Level 3 qualifications are recognised internationally by governments, industry and higher education. BTEC International Level 3 qualifications allow learners to progress to the workplace – either directly or via study at a higher level. Over 100,000 BTEC learners apply to university every year. Their Level 3 BTECs, either on their own or in combination with A Levels, are accepted by UK and international universities, and higher-education institutes for entry to relevant degree programmes.

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 3 qualifications in this suite, we worked with many employers, higher-education providers, colleges and schools to ensure that we met their needs. Employers are looking for recruits who have a thorough grounding in the latest industry requirements and work-ready skills, for example teamwork. Learners who progress to higher education need experience of research, extended writing and meeting deadlines. BTEC qualifications provide the breadth and depth of learning to give learners this experience.

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 higher-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.

Collaborative development

Learners who complete their BTEC International Level 3 qualification in Electrical Automotive Manufacture aim to go on to employment, often via the steppingstone of higher education. It was, therefore, essential that we developed these qualifications in close collaboration experts to ensure that the content meets providers' needs and gives learners quality preparation to help them progress.

Summary of Pearson BTEC International Level 3 Qualifications in Engineering specification Issue 2 change

Summary of changes made between the previous issue and this current issue	**Page numbers**
Suggestions of where sustainability could enhance teaching indicated in unit content in units 2 through 39.	32 through 71

Contents

Introduction to the BTEC International Level 3 qualifications for the engineering sector

This specification contains all the information you need to deliver the Pearson BTEC International Level 3 Qualifications in Electrical Automotive Manufacture. We also refer you to other handbooks and policies.

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 3 Certificate in Engineering (180 GLH)

Pearson BTEC International Level 3 Subsidiary Diploma in Engineering (360 GLH)

Pearson BTEC International Level 3 Foundation Diploma in Engineering (540 GLH)

Pearson BTEC International Level 3 Diploma in Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Electrical and Electronic Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Mechanical Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Digital Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Manufacturing Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Aeronautical Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Mechatronic Engineering (720 GLH)

Pearson BTEC International Level 3 Diploma in Electrical Automotive Manufacture (720 GLH)

Pearson BTEC International Level 3 Extended Diploma in Engineering (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Electrical and Electronic Engineering (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Mechanical Engineering (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Digital Engineering (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Manufacturing Engineering (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Aeronautical Engineering (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Mechatronic Engineering. (1080 GLH)

Pearson BTEC International Level 3 Extended Diploma in Electrical Automotive Manufacture. (1080 GLH)

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 3 Diploma in Electrical Automotive Manufacture	720 GLH Equivalent in size to two International A Levels. 720 GLH, of which 360 GLH is mandatory and at least 240 GLH is assessed by Pearson Set Assignment. Mandatory content - (50%).	This qualification is designed to support learners who want to study electrical automotive manufacture as the main element alongside another area of complementary or contrasting study as part of a two-year, full-time study programme. The qualification would support progression to higher education if taken as part of a programme of study that included other BTEC International Level 3 qualifications or International A Levels.
Pearson BTEC International Level 3 Extended Diploma in Electrical Automotive Manufacture	1080 GLH Equivalent in size to three International A Levels. 1080 GLH, of which 420 GLH is mandatory and at least 240 GLH are assessed by Pearson Set Assignment. Mandatory content - (39%).	This qualification is designed as a full-time course to support learners who want to study travel and electrical automotive manufacture as the main focus of a two-year, full-time study programme. The qualification would support progression to higher education in its own right.

Structures of the qualifications at a glance

This table shows all the units and the qualifications to which they contribute. The full structures for these Pearson BTEC International Level 3 qualifications in Electrical Automotive Manufacture are shown in *Section 2 Structure*. **You must refer to the full structures to select units and plan your programme.**

Key

	Pearson Set Assignment	M	Mandatory units	O	Optional units

Unit (number and title)	Unit size (GLH)	Diploma (720 GLH)	Extended Diploma (1080 GLH)
1 Mechanical Principles	60	M	M
2 Delivery of Engineering Processes Safely as a Team	60	M	M
3 Product Design and Manufacture in Engineering	120	M	M
39 Modern Manufacturing Systems	60	M	M
57 Electrical and Electronic Principles	60	M	M
72 Organisational Efficiency and Improvement	60		M
4 Applied Commercial and Quality Principles in Engineering*	60	O	O
5 A Specialist Engineering Project*	60	O	O
6 Microcontroller Systems*	60	O	O
7 Calculus to Solve Engineering Problems*	60	O	O
8 Further Engineering Mathematics*	60	O	O
9 Work Experience in the Engineering Sector*	60	O	O
10 Computer Aided Design in Engineering*	60	O	O
11 Engineering Maintenance and Condition Monitoring Techniques*	60	O	O
12 Pneumatic and Hydraulic Systems*	60	O	O
13 Welding Technology*	60	O	O
14 Electrical Installation of Hardware and Cables*	60	O	O
15 Electrical Machines*	60	O	O
16 Three-Phase Electrical Systems*	60	O	O
19 Electronic Devices and Circuits*	60	O	O
20 Analogue Electronic Circuits*	60	O	O
21 Electronic Measurement and Testing of Circuits*	60	O	O
25 Mechanical Behaviour of Metallic Materials	60	O	O
30 Mechanical Measurement and Inspection Technology	60	O	O

..continued overleaf

Unit (number and title)	Unit size (GLH)	Diploma (720 GLH)	Extended Diploma (1080 GLH)
33 Computer Systems Security*	60	O	O
36 Programmable Logic Controllers*	60	O	O
40 Computer Aided Manufacturing and Planning*	60	O	O
41 Manufacturing Secondary Machining Processes*	60	O	O
42 Manufacturing Primary Forming Processes*	60	O	O
43 Manufacturing Computer Numerical Control Machining Processes*	60	O	O
44 Fabrication Manufacturing Processes*	60	O	O
45 Additative Manufacturing Processes*	60	O	O
46 Manufacturing Joining, Finishing and Assembly Processes*	60	O	O
47 Composites Manufacture and Repair Processes*	60	O	O
56 Industrial Robotics*	60	O	O
58 Entrepreneurship and Intrapreneurship in Practice*	60	O	O
59 Battery Manufacturing	60	O	O
60 Electric and Hybrid Vehicle Motors	60	O	O
61 Electric Vehicle Drives	60	O	O
62 E-mobility	60	O	O
63 Operation and Testing of Vehicle Electronic Ignition Systems	60	O	O
64 Function and Operation of Vehicle and Braking Systems	60	O	O
65 Vehicle Engine Management Systems	60	O	O
66 Light Vehicle Suspension, Steering and Braking Systems	60	O	O
67 Operation and Maintenance of Light Vehicle Transmission Systems	60	O	O
68 Lean Production System Design	60		O
69 Heavy Vehicle Braking Systems	60	O	O
70 Heavy Vehicle Transmission Systems	60	O	O
71 Heavy Vehicle Steering and Suspension Systems, Wheels and Tyres	60	O	O

* units published separately in the Pearson BTEC International Level 3 Qualifications in Engineering Specification (qualifications.pearson.com/en/qualifications/btec-international-level-3/engineering.html)

Qualification and unit content

Pearson has developed the content of the new BTEC International Level 3 qualifications in collaboration with employers and representatives from higher education, and relevant professional bodies. In this way, we have ensured that content is up to date and that it includes the 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 recognised and valued by higher education and employers. 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 are those such as communication, teamwork and research and analysis, which are valued in both higher education and the workplace. 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.

Centres should ensure that content, for example, content that references regulation, legislation, policies and regulatory/standards organisations, is kept up to date. 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 have extra controls on assessment and are assessed using Pearson Set Assignments. Additionally, some units are synoptic.

Set assignment units

Some mandatory units in the qualifications are assessed using a set assignment. Each assessment is set by Pearson and may need to be taken under controlled conditions before it 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 is available in English but can be translated as necessary.

A learner 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, including synoptic assessment, 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 120 GLH will contribute double that of a 60 GLH unit.

Qualifications in the suite are graded using a scale of P to D*, **or** PP to D*D*, **or** PPP to D*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 3 qualifications in Engineering

Who are these qualifications for?

The Pearson BTEC International Level 3 qualifications in Engineering are designed either for learners in the 16–19 age group, who wish to pursue a career in engineering via higher education to access graduate entry employment with engineers, or alternatively through junior engineering employment.

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 solely on electrical automotive manufacture may take the Extended Diploma, while a learner who selects a Diploma, may choose to combine it with qualifications from other sectors, 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?

Engineering covers a broad variety of roles and involves the application of scientific principles and practical knowledge to transform ideas and materials into products and systems safely, and support them during their lifetime. These qualifications focus on a broad range of engineering specialist areas, including electrical and electronic, mechanical, and others, for example manufacturing.

Learners study mandatory units, including the following topics:

- engineering principles
- health and safety and teamwork
- design and manufacture of products
- manufacturing systems.

Through the optional units, learners will study a mix of vehicle, mechanical and other manufacturing areas.

The content of our engineering qualifications has been developed in consultation with employers and professional bodies to ensure relevance to current industry practice in engineering occupational disciplines. In addition, academics have been consulted on the content development to ensure that the qualifications support progression to higher education.

What could these qualifications lead to?

These qualifications support progression to job opportunities in the engineering sector at a variety of levels. Jobs available in these areas include:

- engineering operative
- vehicle operative
- semi-skilled operative
- battery technician
- electrical automotive technician.

These qualifications also support those following an apprenticeship in engineering who are looking to work and progress in the engineering sector as an engineering technician or as an engineering operative. After completing this qualification, learners can progress directly to technician roles, but it is likely that many will do so via higher education study. These qualifications are recognised by higher education providers as contributing to meeting admission requirements for many relevant courses in a variety of areas of the engineering sector, for example:

- BEng (Hons) in Engineering
- BEng (Hons) in Automotive Engineering
- BSc (Hons) in Computer Science
- BSc (Hons) in Mathematics.

Learners should always check the entry requirements for degree programmes with specific higher education providers.

How do these qualifications provide transferable employability skills?

In the BTEC International Level 3 units, there are opportunities during the teaching and learning phase to give learners practise in developing employability skills. Where we refer to employability 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 2: Transferable employability skills*.

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

All BTEC International Level 3 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. BTEC International Level 3 qualifications provide a vocational context in which learners can develop the knowledge and skills required for particular degree courses, including:

- research skills
- presentation skills
- decision making skills
- selection of appropriate tools and processes used in engineering
- effective writing
- self-management and planning skills
- analytical skills
- preparation for assessment methods used in a degree
- ability to work in legal, ethical and moral manner.

2 Structure

Qualification structures

Pearson BTEC International Level 3 Diploma in Electrical Automotive Manufacture

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

Unit number	Unit title	GLH	How assessed
Group A Mandatory units – learners complete and achieve all units			
1	Mechanical Principles	**60**	Set Assignment
2	Delivery of Engineering Processes Safely as a Team	**60**	Internal
3	Product Design and Manufacture in Engineering	**120**	Set Assignment
39	Modern Manufacturing Systems	**60**	Internal
57	Electrical and Electronic Principles	**60**	Set Assignment
Group B Specialist optional units – learners complete at least 180 GLH			
59	Battery Manufacturing	**60**	Internal
60	Electric and Hybrid Vehicle Motors	**60**	Internal
61	Electric Vehicle Drives	**60**	Internal
62	E–mobility	**60**	Internal
68	Lean Production System Design	**60**	Internal
Group C Optional units – learners complete at least 180 GLH			
4	Applied Commercial and Quality Principles in Engineering*	**60**	Internal
5	A Specialist Engineering Project*	**60**	Internal
6	Microcontroller Systems*	**120**	Set Assignment
7	Calculus to Solve Engineering Problems*	**60**	Internal
8	Further Engineering Mathematics*	**60**	Internal
9	Work Experience in the Engineering Sector*	**60**	Internal
10	Computer Aided Design in Engineering*	**60**	Internal
11	Engineering Maintenance and Condition Monitoring Techniques*	**60**	Internal
12	Pneumatic and Hydraulic Systems*	**60**	Internal
13	Welding Technology*	**60**	Internal

Group C Optional units continued – learners complete at least 180 GLH			
14	Electrical Installation of Hardware and Cables*	**60**	Internal
15	Electrical Machines*	**60**	Internal
16	Three-Phase Electrical Systems*	**60**	Internal
19	Electronic Devices and Circuits*	**60**	Internal
20	Analogue Electronic Circuits*	**60**	Internal
21	Electronic Measurement and Testing of Circuits*	**60**	Internal
25	Mechanical Behaviour of Metallic Materials*	**60**	Internal
30	Mechanical Measurement and Inspection Technology*	**60**	Internal
33	Computer Systems Security*	**60**	Internal
36	Programmable Logic Controllers*	**60**	Internal
40	Computer Aided Manufacturing and Planning*	**60**	Internal
41	Manufacturing Secondary Machining Processes*	**60**	Internal
42	Manufacturing Primary Forming Processes*	**60**	Internal
43	Manufacturing Computer Numerical Control Machining Processes*	**60**	Internal
44	Fabrication Manufacturing Processes*	**60**	Internal
45	Additive Manufacturing Processes	**60**	Internal
46	Manufacturing Joining, Finishing and Assembly Processes*	**60**	Internal
47	Composites Manufacture and Repair Processes*	**60**	Internal
56	Industrial Robotics*	**60**	Internal
58	Entrepreneurship and Intrapreneurship in Practice*	**60**	Internal
63	Operation and Testing of Vehicle Electronic Ignition Systems	**60**	Internal
64	Function and Operation of Vehicle Petrol Injection Systems	**60**	Internal
65	Vehicle Engine Management Systems	**60**	Internal
66	Light Vehicle Suspension, Steering and Braking Systems	**60**	Internal
67	Operation and Maintenance of Light Vehicle Transmission Systems	**60**	Internal
69	Heavy Vehicle Braking Systems	**60**	Internal
70	Heavy Vehicle Transmission Systems	**60**	Internal

Group C Optional units continued – learners complete at least 180 GLH			
71	Heavy Vehicle Steering and Suspension Systems, Wheels and Tyres	**60**	Internal

* units published separately in the Pearson BTEC International Level 3 Qualifications in Engineering Specification (qualifications.pearson.com/en/qualifications/btec-international-level-3/engineering.html)

Pearson BTEC International Level 3 Extended Diploma in Electrical Automotive Manufacture

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

Unit number	Unit title	GLH	How assessed
Group A Mandatory units – learners complete and achieve all units			
1	Mechanical Principles	**60**	Set Assignment
2	Delivery of Engineering Processes Safely as a Team	**60**	Internal
3	Product Design and Manufacture in Engineering	**120**	Set Assignment
39	Modern Manufacturing Systems	**60**	Internal
57	Electrical and Electronic Principles	**60**	Set Assignment
72	Organisational Efficiency and Improvement	**60**	Internal
Group B Specialist optional units – learners complete at least 240 GLH			
59	Battery Manufacturing	**60**	Internal
60	Electric and Hybrid Vehicle Motors	**60**	Internal
61	Electric Vehicle Drives	**60**	Internal
62	E–mobility	**60**	Internal
68	Lean Production System Design	**60**	Internal
Group C Optional units – learners complete at least 420 GLH			
4	Applied Commercial and Quality Principles in Engineering*	**60**	Internal
5	A Specialist Engineering Project*	**60**	Internal
6	Microcontroller Systems*	**120**	Set Assignment
7	Calculus to Solve Engineering Problems*	**60**	Internal
8	Further Engineering Mathematics*	**60**	Internal
9	Work Experience in the Engineering Sector*	**60**	Internal
10	Computer Aided Design in Engineering*	**60**	Internal
11	Engineering Maintenance and Condition Monitoring Techniques*	**60**	Internal
12	Pneumatic and Hydraulic Systems*	**60**	Internal
13	Welding Technology*	**60**	Internal
14	Electrical Installation of Hardware and Cables*	**60**	Internal
15	Electrical Machines*	**60**	Internal
16	Three-Phase Electrical Systems*	**60**	Internal

Group C Optional units continued – learners complete at least 420 GLH			
19	Electronic Devices and Circuits*	**60**	Internal
20	Analogue Electronic Circuits*	**60**	Internal
21	Electronic Measurement and Testing of Circuits*	**60**	Internal
25	Mechanical Behaviour of Metallic Materials*	**60**	Internal
30	Mechanical Measurement and Inspection Technology*	**60**	Internal
33	Computer Systems Security*	**60**	Internal
36	Programmable Logic Controllers*	**60**	Internal
40	Computer Aided Manufacturing and Planning*	**60**	Internal
41	Manufacturing Secondary Machining Processes*	**60**	Internal
42	Manufacturing Primary Forming Processes*	**60**	Internal
43	Manufacturing Computer Numerical Control Machining Processes*	**60**	Internal
44	Fabrication Manufacturing Processes*	**60**	Internal
45	Additive Manufacturing Processes*	**60**	Internal
46	Manufacturing Joining, Finishing and Assembly Processes*	**60**	Internal
47	Composites Manufacture and Repair Processes*	**60**	Internal
56	Industrial Robotics*	**60**	Internal
58	Entrepreneurship and Intrapreneurship in Practice*	**60**	Internal
63	Operation and Testing of Vehicle Electronic Ignition Systems	**60**	Internal
64	Function and Operation of Vehicle Petrol Injection Systems	**60**	Internal
65	Vehicle Engine Management Systems	**60**	Internal
66	Light Vehicle Suspension, Steering and Braking Systems	**60**	Internal
67	Operation and Maintenance of Light Vehicle Transmission Systems	**60**	Internal
69	Heavy Vehicle Braking Systems	**60**	Internal
70	Heavy Vehicle Transmission Systems	**60**	Internal
71	Heavy Vehicle Steering and Suspension Systems, Wheels and Tyres	**60**	Internal

* units published separately in the Pearson BTEC International Level 3 Qualifications in Engineering Specification (qualifications.pearson.com/en/qualifications/btec-international-level-3/engineering.html)

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 1: Mechanical Principles	· An assignment set by Pearson and marked by the centre, completed under supervised conditions. · The recommended assessment time is two hours.	**Two available for each series.**
Unit 3: Product Design and Manufacture in Engineering	· An assignment set by Pearson and marked by the centre, completed under supervised conditions. · The recommended assessment time is three hours for Part A and eight hours for Part B.	**Two available for each series.**
Unit 6: Microcontroller Systems	· An assignment set by Pearson and marked by the centre, completed under supervised conditions. · The recommended assessment time is 12 hours.	**Two available for each series.**
Unit 57: Electrical and Electronic Principles	· An assignment set by Pearson and marked by the centre, completed under supervised conditions. · The recommended assessment time is two hours.	**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.

Some units are published separately in the Pearson BTEC International Level 3 Qualifications in Engineering Specification (qualifications.pearson.com/en/qualifications/btec-international-level-3/engineering.html)

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 3.
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 120 or 60. 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 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.
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 learning aims in *Appendix 3: Glossary of terms used*.
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.

Section	Explanation
Assessment criteria	Each learning aim has Pass and Merit criteria. Each assignment has at least one Distinction criterion. A full glossary of terms used is given in *Appendix 3: Glossary of terms used.* All assessors need to understand our expectations of the terms used. 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. 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.
Links to other units	This section shows you the main relationships between different units. 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 the automotive manufacture units developed for these qualifications. The remaining units are published separately in the Pearson BTEC International Level 3 Qualifications in Engineering Specification (qualifications.pearson.com/en/qualifications/btec-international-level-3/engineering.html)

Please refer to *pages 4–5* to check which units are available in all qualifications in the engineering sector.

Unit 1: Mechanical Principles

Level: 3
Unit type: Internal set assignment
Guided learning hours: 60

Unit in brief

Learners will develop the skills and knowledge required to solve mechanical-based engineering problems by applying mathematical and physical science principles.

Unit introduction

Modern life depends on engineers to develop, support and control the mechanical products and systems that are all around us, for example cars, machinery and manufacturing and transport systems. To make a contribution as an engineer, you must be able to draw on an important range of principles developed by early engineering scientists, such as Archimedes, Isaac Newton and James Watt.

There is an increasing demand for 'multi-skilled' engineers who can apply principles from several engineering disciplines to develop solutions to engineering problems. This unit will develop your mathematical and physical scientific knowledge, and understanding to enable you to solve problems set in an engineering context. You will explore and apply the algebraic and trigonometric mathematical methods required to solve engineering problems. The mathematical and physical science principles covered in this unit' or 'the engineering principles covered in this unit.

This sits at the heart of the qualification and gives you a foundation to support you in any engineering technician role, a trainee job role with an employer, or to help with your progression to higher education.

Assessment

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

Learning aims

In this unit you will:

A Examine how algebraic and trigonometric mathematical methods can be used to solve engineering problems

B Examine how static engineering systems can be used to solve engineering problems

C Examine how dynamic engineering systems can be used to solve engineering problems

D Examine how fluid engineering systems can be used to solve engineering problems.

Content

Learning aim A: Examine how algebraic and trigonometric mathematical methods can be used to solve engineering problems

Application of appropriate units. Application of rounding: decimal places and significant figures.

A1 Algebraic methods

Solve, transpose and simplify equations.

- Routine methods:
  - linear equations and straight-line graphs
    - linear equations of the form $y = mx + c$
    - straight-line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line)
  - Pythagoras' theorem
  - standard mensuration formulae to solve surface areas and volumes of regular shapes and solids:
    - volume of a cylinder $V = \pi r^2 h$
    - total surface area of a cylinder $TSA = 2\pi rh + 2\pi r^2$
    - volume of sphere $V = \frac{4}{3}\pi r^3$
    - surface area of a sphere $SA = 4\pi r^2$
    - volume of a cone $V = \frac{1}{3}\pi r2h$
    - curved surface area of cone $CSA = \pi rl$

Factorisation and quadratics:

- Routine methods
  - multiply expressions in brackets by a number, symbol or by another expression in a bracket
  - grouping $ax - ay + bx - by$
  - roots of an equation, including quadratic equations with real roots by factorisation.
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - mensuration
    - standard formulae to solve surface areas and volumes of compound solids formed from:
      - cuboids
      - triangular prisms
      - spheres and hemispheres
      - cylinders
      - cones
  - factorisation and quadratics
    - extraction of a common factor $ax + ay$, $a(x + 2) + b(x + 2)$
    - expressions $a2 + 2ab + b2$, $a2 - bx + c$
    - roots of an equation, including quadratic equations with real roots by the use of formula
    - quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

A2 Trigonometric methods

- Routine methods:
  - circular measure
    - radians, where 2p radians = 360°
    - conversion of radian measure to degree measure θdegrees = $\frac{360\,\theta_{radians}}{2\text{p}}$
    - conversion of degree measure to radian measure $\theta_{radians} = \frac{2\text{p}\,\theta_{degrees}}{360}$
    - angular rotations (multiple number (n) of radians)
    - problems involving areas and angles measured in radians:
  - length of arc of a circle $s = r\theta$
  - area of a sector $A = \frac{1}{2}r^2\theta$
  - triangular measurement
    - functions (sine, cosine and tangent)
    - sine/cosine wave over one complete cycle
    - values of the trigonometric ratios for angles between 0° and 360°
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - triangular measurement
    - graph of tan$A$ as A varies from 0° and 360°, $\tan A = \frac{\sin A}{\cos A}$
    - the sine $\frac{a}{sin\,A} = \frac{b}{sin\,B} = \frac{c}{sin\,C}$ and cosine rule $a^2 = b^2 + c^2 - 2b\cos A$
    - application of vectors
  - diagrammatic representation of vectors
  - resolution of forces/velocities.

Learning aim B: Examine how static engineering systems can be used to solve engineering problems

Application of appropriate units. Application of rounding: decimal places and significant figures.

B1 Static engineering systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems, involving the following.

- Routine methods:
  - non-concurrent coplanar forces
    - representation of forces using space and free body diagrams
    - resolution of forces in perpendicular directions $Fx = F\cos\theta$, $Fy = F\sin\theta$
    - conditions for static equilibrium $\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma M = 0$
  - simply supported beams involving either
    - concentrated loads
    - uniformly distributed loads (UDL)
  - reactions
    - support reactions
    - pin reaction forces
    - roller reaction forces.

- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - non-concurrent coplanar forces
    - turning moments
    - vector addition of forces: resultant, equilibrant and line of action
  - simply supported beams
    - beams with combinations of concentrated loads and uniformly distributed loads (UDL).

B2 Loaded components

Recall, perform procedures, demonstrate an understanding of, and analyse information and systems involving the following.

- Routine methods:
  - direct stress and strain: direct stress $\sigma = \frac{F}{A}$, direct strain $\varepsilon = \frac{\Delta l}{l}$
  - shear stress and strain: shear stress $t = \frac{F}{A}$, shear strain $g = \frac{a}{b}$
  - definitions of tensile and shear strength
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - elastic constants: modulus of elasticity $E = \frac{\sigma}{\varepsilon}$; Modulus of rigidity $G = \frac{t}{g}$

Learning aim C: Examine how dynamic engineering systems can be used to solve engineering problems

Application of appropriate units. Application of rounding: decimal places and significant figures.

C1 Kinetic parameters

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

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

C2 Dynamic parameters

Recall, perform procedures, demonstrate an understanding of, and analyse information and systems, involving the following.

- Routine methods:
  - dynamic parameters and principles
    - acceleration due to gravity (g = 9.81 m/s^2)
    - force $F = ma$
    - torque $T = Fd$
    - mechanical work $W = Fs$ (on a horizontal plane)

- mechanical power (average and instantaneous)
- mechanical $h = \frac{P_{out}}{P_{in}}$ efficiency
- energy – gravitational potential energy $PE = mgh$, kinetic energy $KE = \frac{1}{2}mv^2$
- Momentum = mv

· Non-routine methods involve the following topics and/or multiple steps to make connections:

o dynamic parameters and principles
- Newton's laws of motion
- Mechanical work (on an inclined plane)
- principles of conservation of momentum $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
- principles of conservation of energy
- Rotational inertia $I = kmr^2$ where the inertial constant for a solid cylinder (flywheel) $k = ½$ and for a thin walled hollow cylinder $k \approx 1$ (along the axis of rotation).

C3 Angular parameters

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

· Routine methods:

o angular parameters
- angular velocity $\omega = \frac{\theta}{t} = \frac{s}{rt} = \frac{v}{r}$
- centripetal acceleration $a = w^2r = \frac{v^2}{r}$

· Non-routine methods involve the following topics and/or multiple steps to make connections:

o angular parameters
- uniform circular motion
- power = Tw
- rotational kinetic energy $KE = \frac{I\omega^2}{2}$
- angular frequency $\omega = 2\pi f$

C4 Lifting machines

Recall, perform procedures, demonstrate an understanding of, and analyse information and systems involving the following routine methods:

Routine methods

· Lifting machines, including:

o inclined planes, scissor jacks, pulleys

o velocity ratio $VR = \frac{driver}{driven} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$
- mechanical advantage $MA = \frac{load}{effort}$
- effort and load motion
- friction effects on a horizontal plane
- force to overcome friction on a horizontal plane $F = \mu N$ (where N is the normal force).

· Non-routine methods involve the following topics and/or multiple steps to make connections:

- Friction effects on an inclined plane
- force to overcome friction on an inclined plane $F = \mu N$ (where N is the normal force).

Learning aim D: Examine how fluid engineering systems can be used to solve engineering problems

Application of appropriate units. Application of rounding: decimal places and significant figures.

D1 Fluid systems

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

- Routine methods:
  - submerged surfaces in fluid systems
    - density of fluid $\rho = \frac{m}{V}$
    - hydrostatic pressure and hydrostatic thrust on an immersed plane surface $F = rgAx$
    - centre of pressure of a rectangular retaining surface with one edge in the free surface of a liquid
    - centre of pressure of a rectangular retaining surface with one edge in the free surface of a liquid $x = \frac{h}{3}$
  - fluid flow in a gradually tapering pipe
    - volumetric flow rate
    - flow velocities (input and output)
    - input and output pipe diameters
    - incompressible fluid flow (continuity of volumetric flow $A_1v_1 = A_2v_2$
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - submerged surfaces in fluid systems
    - overturning moments
  - fluid flow in a gradually tapering pipe
    - mass flow rate (volumetric and mass [$\rho A_1v_1 = \rho A_2v_2$]).

D2 Immersed bodies

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following routine methods.

- Routine methods
  - Immersed bodies:
    - Archimedes' principle
    - determination of density using flotation methods
    - relative density of liquids and solids.

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Examine how algebraic and trigonometric mathematical methods can be used to solve engineering problems</td><td rowspan="2">A.D1 Solve routine and non-routine problems accurately, using algebraic and trigonometric methods.</td></tr>
<tr><td>A.P1 Solve given routine problems using algebraic methods.
A.P2 Solve given routine problems using trigonometric methods.</td><td>A.M1 Solve routine problems accurately and non-routine problems using both algebraic and trigonometric methods.</td></tr>
<tr><td colspan="2">Learning aim B: Examine how static engineering systems can be used to solve engineering problems</td><td rowspan="5">BCD.D2 Solve routine and non-routine problems accurately using mechanical engineering methods.</td></tr>
<tr><td>B.P3 Solve routine problems that involve both static systems.
B.P4 Solve routine problems that involve loaded components.</td><td>B.M2 Solve routine problems accurately and non-routine problems that involve both static systems and loaded components.</td></tr>
<tr><td colspan="2">Learning aim C: Examine how dynamic engineering systems can be used to solve engineering problems</td></tr>
<tr><td>C.P5 Solve routine problems that involve kinetic and dynamic parameters.
C.P6 Solve routine problems that involve angular parameters.</td><td>C.M3 Solve routine problems accurately and non-routine problems that involve dynamic systems.</td></tr>
<tr><td colspan="2">Learning aim D: Examine how fluid engineering systems can be used to solve engineering problems</td></tr>
<tr><td>D.P7 Solve routine problems that involve fluid systems.
D.P8 Solve routine problems that involve immersed bodies.</td><td>D.M4 Solve routine problems accurately and non-routine problems that involve fluid systems.</td></tr>
</table>

Essential information for assignments

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

Learners will be required to interpret and use data and information relating to engineering scenarios.

Learners' work will be submitted in the form of a completed assignment, which will be assessed by centre staff using the assessment criteria in this unit.

Further information for teachers and assessors

Resource requirements

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

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners must show a full range of progressive steps when producing solutions to problems that may include minimal errors such as those associated with transposition, rounding and standard form, particularly for the non-routine problems. They will demonstrate good use of methods, including a concise approach to reaching solutions. Working will be neat and well presented, and will follow a logical structure.

Learners will demonstrate an appropriate choice of units and, where necessary, accurate use of standard form. Solutions will be provided to an appropriate degree of precision and be presented in their simplest form. Learners may also include some evidence of checking answers and they will possibly make amendments as a result.

For Merit standard, learners must produce solutions for routine and non-routine problems. For routine problems, most working should be completed with accuracy, and will demonstrate correct use of appropriate methods.

For non-routine methods, learners may demonstrate some errors in their working, such as obvious omissions and transposition, rounding and/or conversion errors. Some inappropriate use of standard form is also likely, although where arithmetic errors have been made, these are likely to be carried through in subsequent working.

For Pass standard, learners must show solutions that are logical in the choice of methods to be followed. Solutions to problems that involve routine methods are likely to involve some errors but will be followed through to a plausible solution. Use of standard form will not be evident or may be used inaccurately.

Learning aims B, C and D

For Distinction standard, learners must show a full range of progressive steps when producing concise solutions for a range of mechanical engineering problems. They will interpret the information provided and then demonstrate correct use of methods, although some minor errors may be present in working such as those associated with transposition, rounding and standard form for non-routine problems. Learners will recognise links between different aspects of mechanical engineering problems and will produce solutions that follow a logical structure.

Learners will demonstrate an appropriate choice of units and, where necessary, accurate use of standard form. Solutions will be provided to an appropriate degree of precision and will be presented in their simplest form. Learners may also include some evidence of checking answers and they will possibly make amendments as a result.

For Merit standard, learners must produce solutions to a range of static, dynamic and fluid engineering problems that involve the use of both routine and non-routine methods. For routine methods, most working will be completed with accuracy and learners will demonstrate correct use of appropriate methods to solve each type of problem.

For non-routine methods, learners may demonstrate some errors in their working, such as obvious omissions and transposition, rounding and/or conversion errors, or taking approaches that are not obvious but which arrive at suitable solutions. Some inappropriate use of standard form is also likely, although where arithmetic errors have been made these are likely to be carried through in subsequent working.

For Pass standard, learners must show solutions to routine static, dynamic and fluid engineering problems that are logical in the choice of methods to be followed.

Solutions to routine problems are likely to include some errors but be followed through to a plausible solution. Use of standard form will not be evident or may be used inaccurately.

Assessment controls

Time: the assignment must be completed in the stated time for the assignment.

Invigilation: learners should be invigilated and on centre premises when completing the assignment.

Resources: resources and learners' work should be kept securely in the centre between assessment periods.

Research: learners may need to research their local environment to collect data to support their response. If this is the case, they are permitted to take notes and bring them back to the centre. Research time will be accounted for in the time requirement for the assignment.

Links to other units

This unit links to:

- Unit 2: Delivery of Engineering Processes Safely as a Team
- Unit 3: Engineering Product Design and Manufacture
- Unit 57: Electrical and Electronic Principles.

Opportunities to develop transferable employability skills

Learners will have the opportunities to develop the following transferable skills in the completion and assessment of this unit.

- Learners will use formal written documentation to present research findings from intensive investigations into topics and themes. From conducting this documentation learners will be able to apply mathematical methods to solve engineering problems.
- Learners will take part in structured activities and tasks to enable them to solve static, dynamic and fluid engineering problems, using routine and non-routine operations.
- Independent tracking and monitoring of project work as it develops.

Unit 2: Delivery of Engineering Processes Safely as a Team

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners explore how processes are undertaken by teams to create engineered products or to deliver engineering services safely.

Unit introduction

The use of engineering processes is integral to the manufacture of engineered products and the delivery of engineering services. Thousands of engineering processes are used in the manufacture and service of a complex product such as an aeroplane. To ensure that these engineering processes can be planned and carried out safely and effectively, engineers must be able to work together to get the job done. It is for this reason that so many engineering companies focus time and effort on understanding engineering processes and developing teamwork.

In this unit, you will examine common engineering processes, including health and safety legislation, regulations that apply to these processes and how individual and team performance can be affected by human factors. You will learn the principles of another important process, engineering drawing, and develop two-dimensional (2D) computer-aided drawing skills while producing orthographic projections and circuit diagrams. Finally, you will work as a team member and team leader to apply a range of practical engineering processes to manufacture a batch of an engineered product or to safely deliver a batch of an engineering service. To complete the assessment task within this unit, you will need to draw on your learning from across your programme.

It is important that engineers understand how engineering processes are used to safely transform ideas and materials into products and services, and how critical it is to be able to work as a valuable member of an effective team or as a team leader. This unit will enable you to apply the knowledge and understanding you gained in *Unit 1: Mechanical Principles* and *Unit 57: Electrical and Electronic Principles*. The unit will help to prepare you for an engineering traineeship, a higher education engineering degree or a technician-level role in a wide range of specialist engineering areas.

Learning aims

In this unit you will:

A Examine common engineering processes to create products or deliver services safely and effectively as a team

B Develop two-dimensional computer-aided drawings that can be used in engineering processes

C Carry out engineering processes safely to manufacture a product or to deliver a service effectively as a team.

Content

Learning aim A: Examine common engineering processes to create products or deliver services safely and effectively as a team

A1 Common engineering processes

- Transforming ideas and materials into products or services, including:
  - preparation processes undertaken before manufacture or service delivery – use of information sources and the creation of technical specifications, engineering drawings, work plans and quality control documentation with due regard to the scale of production (one-off, small batch, large batch, mass or continuous)
  - standards relevant to the specialist area of study – guidelines/rules to ensure conformity in processes or outputs, e.g. BS 8888, reference charts (limits and fits, tapping drills, bend allowances), procedure specifications.
- A product and a service are closely aligned concepts, define:
  - a product as a tangible and discernible item, e.g. a car
  - a service as an intangible benefit, either in its own right or as a significant element of a tangible product, e.g. a car service.
- Common processes used to create engineered products, including:
  - fitting, e.g. at a bench using manual tools (drilling, cutting, filing)
  - machining, e.g. turning, milling, grinding
  - fabrication, e.g. welding, sheet metal work (bending, stamping, punching)
  - electrical, e.g. installation of looms, use of connectors/cables
  - forming, e.g. casting, forging, moulding.
- Common processes used in engineering services, including:
  - disassembly, e.g. use of general tools and special tools to strip or remove
  - inspection, e.g. checking for faults/correct operation, testing
  - systems servicing, e.g. capture of fluid, depressurisation
  - installation/replacement, e.g. rigging, assembly, refitting.

A2 Health and safety requirements

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

- current Health and Safety at Work legislation – duties of employers, employees, the Health and Safety Executive (HSE) and others, general prohibitions
- current Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) – duties of employers, the self-employed and people in control of work premises (the Responsible Person) to report certain serious workplace accidents, occupational diseases and specified dangerous occurrences
- current Personal Protective Equipment (PPE) at Work Regulations – appropriateness if risk cannot be controlled in any other way, types of PPE, assessing suitable PPE given the hazard, supply, instructions/training, correct use, maintenance and storage
- current Control of Substances Hazardous to Health Regulations (COSHH) – identifying harmful substances, assessing risks of exposure, types of exposure, safety data sheets, using/checking/maintaining control measures/equipment, training/instruction/information

- current Manual Handling Operations Regulations (MHOR) – avoiding the need for manual handling, types of hazard, assessing risk of injury when manual handling is required, controlling and reducing the risk of injury, training in the use of techniques/mechanical aids.

A3 Human factors affecting the performance of engineering processes

- Understanding that human factors affect the productivity of processes, including conformance to quality standards, reliability and the safety of individuals.
- Understanding that human factors affect the performance of individuals and teams, including:
  - professionalism – adherence to codes of conduct, acting with due care, skill and diligence by recognising appropriate behaviours and possible limitations, preventing avoidable dangers/adverse impact on the environment, enhancing operational competence
  - ethical principles – rigour, honesty, integrity, respect, responsibility
  - behaviours – values, attitude, persuasion, coercion, rapport, authority
  - limitations – stress, time pressure, fatigue, memory, capability, motivation, knowledge, experience, health, inhibitors, e.g. alcohol and drugs.

Learning aim B: Develop two-dimensional computer-aided drawings that can be used in engineering processes

B1 Principles of engineering drawing

- Attributes of orthographic projections, including:
  - geometry – shape of the component represented as different views, how the component is viewed from various angles, visibility of component features
  - dimensions – size of the component in defined units
  - tolerances – allowable variations for defined dimensions
  - material – what the component is to be made from
  - surface texture – surface quality required, e.g. roughness, flatness
  - scale – relative to actual dimensions.
- Drawing conventions or other relevant international equivalents, including:
  - standards including BS 8888 and BS 60617 or other relevant international equivalents
  - title block/layout – drawing number(s), projection symbols, scale, units, general tolerances, name of author, date, border, parts referencing
  - views – elevation, plan, end, section, hatching style, auxiliary
  - line types – centre, construction, outline, hidden, leader, dimension
  - common features, e.g. screw threads, springs, splines, repeated items, holes, chamfers, radii
  - circuit diagram symbols and components, e.g. cell/battery, switch, resistor, diode, capacitor, transistor, integrated circuit, light-emitting diode (LED), motor, buzzer
  - lettering – titles, notes, annotation
  - abbreviations – A/F, CHAM, DIA, R, PCD, M.

B2 2D computer-aided drawing

Using a computer-aided design (CAD) system to produce engineering drawings and circuit diagrams, including:

- coordinates – absolute, relative, polar
- drawing template – border, title block with all necessary information
- layers – names, line types, colours, visibility
- commands – line, circle, arc, polygon, chamfer, fillet, grid, snap, copy, rotate, erase, stretch, trim, scale, dimensioning, text, pan, zoom-in, zoom-out, insertion and editing commands to produce and erase circuit components and connections
- cross-hatching – simple and complex areas, predefined hatch patterns, application to cross-sectioning.

Learning aim C: Carry out engineering processes safely to manufacture a product or to deliver a service effectively as a team

C1 Principles of effective teams

- Good communication – verbal, written (e.g. electronic documents and data, activity logs, meeting minutes), effective listening, respect for others' opinions, negotiation, assertiveness and non-verbal actions, e.g. smiling.
- Planning – thinking ahead, organisation, consideration of alternatives.
- Motivation – shared goals, collaboration, reaching agreements, adapting behaviour, fairness and consideration, opportunities to take responsibility, constructive feedback.
- Working with others – team player, flexibility/adaptability, social skills, supporting others, reasons why teams should be diverse.
- Working environment – conducive to successful outcomes, safe, supportive, challenging, opportunities to show initiative and leadership.

C2 Team set-up and organisation

- A team is defined as containing three or more individual members who have a shared common objective to complete.
- Strengths and limitations of team members – perceived competencies and constructive peer feedback.
- Allocation of responsibilities – roles, activities.
- Timescales – planning the activities.
- Objectives – team targets.

C3 Health and safety risk assessment

Risk assessment in an engineering workshop and for specific engineering processes, following guidance from the HSE (or other relevant international equivalents), including:

- identification of hazards – bad housekeeping, poor lighting, lack of grip/uneven surfaces/heights, lifting and handling operations, hand tools, machines, substances, heat/flammability
- assessing risk by determining how hazards can cause injury – contact, being struck, lifting and handling injury, fall, slip, trip, trap, exposure

- choosing and using appropriate control measures and precautions to reduce risk – good work area design, substitution, safe means of access and egress, safe system of work (permits to work), periodic inspection, testing and maintenance, physical barriers (guarding), PPE, supervision and training, good housekeeping, cleaning regime
- recording all findings – standard HSE (five steps) pro forma
- reviewing the risk assessment after new equipment/work activities have been undertaken, at regular intervals.

C4 Preparation activities for batch manufacture or batch service delivery

- A batch is defined as a quantity of three or more of a product or service delivered together.
- Understanding the requirements of production plans, specifications, engineering drawings and other technical documentation, including:
  - operations – sequence of production
  - health and safety factors – product or service based
  - processes – disassembly, mechanical, electrical, assembly, testing
  - materials, parts and components – to be disassembled, worked on, processed, joined, assembled and checked
  - equipment – marking out, hand tools, machinery, measuring
  - quality checks – critical production control points, how quality will be checked and inspected.

C5 Delivery of manufacturing or service engineering processes

- For engineered products or engineering services.
- Examples of engineered products, e.g. screwdriver, toolmakers' clamp, fabricated box/enclosure, outside calipers, ball joint splitter, clamp stand, assembling looms.
- Selecting, setting up and using engineering equipment to manufacture engineered products in an efficient and sustainable manner, including:
  - marking out processes, e.g. using a scriber, rule/tape, punch, square, vernier height gauge, marking out medium
  - manual processes, e.g. using shears, punch, guillotine, bender, saw, tap, die, file
  - machining processes, e.g. using a drill, lathe, milling machine
  - assembly processes, e.g. using adhesive, mechanical fasteners, cables/connectors
  - quantity production, e.g. using form tools, template, jig, mould, fixture, stops
  - measuring processes, e.g. using a micrometer, vernier calipers, comparators.
- Examples of engineering services, e.g. dismantling/assembly of alternators, including replacing worn parts and testing, removing and replacing fluid plumbing and checking for leaks, stripping out a variety of hardware and reinstalling/testing, assembly of pipework, including the connection of valves and operational checks, assembly and testing of electrical switch panels.

- Selecting, setting up and using engineering equipment to deliver engineering services in an efficient and sustainable manner, including:
  - disassembly/removal/strip processes, e.g. using a screwdriver, wrench, spanner, sockets, pliers/grips, keys
  - manual processes, e.g. using snips, cutters, knives, punch, saw, file, hammer
  - assembly processes, e.g. using a soldering iron, mechanical fasteners, cables/connectors, crimping tools, pneumatic tools, clamps
  - inspection/testing processes, e.g. using a multimeter, flow meter, torque meter, pressure sensor/gauge.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Examine common engineering processes to create products or deliver services safely and effectively as a team		A.D1 Evaluate, using language that is technically correct, the effectiveness of using different engineering processes to manufacture a product or to deliver a service and how human factors, as an individual and as a team, affect the performance of engineering processes.
A.P1 Explain how three engineering processes are used safely when manufacturing a given product or when delivering a given service. A.P2 Explain how human factors, as an individual or as a team, affect the performance of engineering processes.	A.M1 Analyse why three engineering processes are used to manufacture a product or to deliver a service and how human factors, as an individual and as a team, affect the performance of engineering processes.	
Learning aim B: Develop two-dimensional computer-aided drawings that can be used in engineering processes		B.D2 Refine, using layers, an accurate orthographic projection of a component containing at least three different common feature types and a circuit diagram containing at least six different component types to an international standard.
B.P3 Create an orthographic projection of a given component containing at least three different feature types. B.P4 Create a diagram of a given electronic circuit containing at least six different component types.	B.M2 Produce, using layers, an accurate orthographic projection of a component containing at least three different feature types and a circuit diagram containing at least six different component types that mostly meet an international standard.	

Cont.

Pass	Merit	Distinction
Learning aim C: Carry out engineering processes safely to manufacture a product or to deliver a service effectively as a team		
C.P5 Manage own contributions to set up and organise a team in order to manufacture a product or deliver a service. C.P6 Produce, as an individual team member, a risk assessment of at least one engineering process. C.P7 Set up, as an individual team member, at least one process safely by interpreting technical documentation. C.P8 Manage own contributions safely, as a team member and as a team leader, to manufacture a batch of an engineered product or to deliver a batch of an engineering service.	C.M3 Manage own contributions safely and effectively using feedback from peers, as a team member and as a team leader, to manufacture a product or to deliver a service.	C.D3 Consistently manage own contributions effectively using feedback from peers, as a team member and as a team leader, to set up, organise and manufacture a product or deliver a service safely, demonstrating forward thinking, adaptability or initiative.

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) could be assessed through a report, prepared as an individual, detailing engineering processes and the impact that human factors can have on their performance, using a case study based on a given engineered product/ products or a given engineering service/services.

Learning aim: B (B.P3, B.P4, B.M2, B.D2) could be assessed through practical activities to be undertaken as an individual to produce 2D computer-aided drawings. The drawings should include an orthographic projection and an electric circuit diagram. The evidence will include the drawings, observation records/witness statements and annotated screenshots.

Learning aim: C (C.P5, C.P6, C.P7, C.P8, C.M3, C.D3) could be assessed through practical engineering processes as a leader and as a member of a team. The evidence will include records of team meetings (minutes), activity logs, a risk assessment, set-up planning notes, quality control charts/ annotated drawings, modified production plans, annotated photographs of the processes and observation records/witness statements.

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to:

- a range of technical documentation (such as engineering drawings, production plans, specifications, health and safety regulations), components and circuits
- suitable CAD workstations and output devices, e.g. printers and plotters, and 2D CAD software that is capable of professional 2D drawings and their output, e.g. AutoCAD 2D, AutoCAD Lt, TurboCAD Deluxe, DraftSight®
- standard engineering workshop equipment and resources (as specified in the learning aims and unit content section), so learners can carry out common engineering processes to manufacture an engineered product batch or deliver an engineering service as a member of a team.

Essential information for assessment decisions

Learning aim A

The processes to be considered for learning aim A do not have to be the same as those used for learning aim C.

For Distinction standard, learners will produce evidence that evaluates the relative merits of using different common engineering processes to manufacture a given product or deliver a given service, by comparing and contrasting the advantages and limitations of the chosen processes and of using other possible processes. Learners will provide detailed and justified reasons as to which processes are most effective, by referring to the specific requirements of the given product or service, for example by considering why a product is cast rather than machined, or whether to test or disassemble at a given interval.

Learners will also produce evidence that shows they can evaluate the impact that a range of human factors, as an individual and as a team, can have on the performance of engineering processes, for example how coercion by someone in authority could lead to an individual or team introducing unnecessary hazards and risks into the engineering processes.

Overall, the evidence will be easy to read by a third party, who may or may not be an engineer, and will be easily understood. It will be logically structured and will use correct technical engineering terms and consistent use of correct grammar and spelling.

For Merit standard, learners will produce evidence that shows they can give detailed reasons as to why three common engineering processes have been chosen to manufacture a given product or to deliver a given service. The analysis will be consistent across all the processes and will include a contextual commentary. For example, for each process it will refer to scale of manufacture, the achievement of accuracy in comparison to a standard, and specific health and safety requirements.

Learners will also produce contextual evidence that shows they can analyse how human factors, as an individual and as a team, can impact on the performance of the three common engineering processes, for example by anticipating and preventing common errors, avoidable dangers or adverse impacts on the environment.

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

For Pass standard, learners will produce evidence that shows they understand how three common engineering processes are used to manufacture a product or deliver a service. The evidence will be factually accurate and will include clear references to health and safety legislation and regulations, for example how drilling, turning and milling are used to produce a given product/products, or how to dismantle and replace worn parts and test an item using safe working practices and personal protective equipment, including why and how to report a dangerous occurrence during a process.

Learners will also produce evidence that shows they recognise the impact that human factors, either as an individual or as a team, can have on the three common engineering processes, for example the productivity of the processes being affected by an individual's attitude or capability, or safety being affected by fatigue.

Overall, the explanations may be basic in parts and may have some inaccuracies relating to engineering terminology.

Learning aim B

The orthographic drawings must be created on a 2D CAD package and not on a 3D CAD package. The component and electrical circuit to be drawn for learning aim B do not have to be used for learning aims A or C. The drawing should be created from an actual engineered component that must contain at least three different types of common feature. Learners will create the drawings using the knowledge and understanding gained in *Unit 1: Mechanical Principles* and *Unit 57: Electrical and Electronic Principles*. For example, taking measures from and performing calculations using the physical component, which could include geometry/vectors, basic arithmetic, trigonometry, and surface area and volume.

For Distinction standard, learners will show in their evidence that they used a full range of CAD commands when generating the drawings and prepared and used additional layers as required for the drawing template, dimensioning and annotation.

Overall, all details in the 2D CAD orthographic projection and the electrical circuit diagram must be produced to typically represent the standards found in BS 8888 and BS 60617 (or other relevant international equivalents), with no omissions or errors evident.

For Merit standard, learners will show in their evidence that they used a layer for a drawing template with a full title block, border and appropriate text.

Overall, all details in the 2D CAD orthographic projection and the electrical circuit diagram must be produced to typically represent the standards found in BS 8888 and BS 60617 (or other relevant international equivalents), although there may be some minor errors evident, such as the lack of a visible gap between some features of the component and extension lines, or some text that is incorrectly orientated.

For Pass standard, learners will produce elevations that are technically correct but there may be some errors, such as a repeated dimension or inaccurate annotation.

Overall, all details in the 2D CAD orthographic projection drawing and the electric circuit diagram must be suitable for a competent third party to manufacture the component or the electric circuit from the drawings.

Learning aim C

Learners will work as a team to deliver an engineering service or to manufacture a product. They will use the knowledge and understanding gained in *Unit 1: Mechanical Principles* and *Unit 57: Electrical and Electronic Principles* to undertake and manage a practical service or manufacturing task. During assessment, a team should manufacture a batch of an engineered product or deliver a batch of an engineering service, not both. The choice is likely to be dependent on the sector context and/or the resources available. All planning and manufacturing or service activities should take no more than 15 hours in total. A team should consist of three or four learners and it is expected that the role of team leader will be undertaken by all team members (in rotation) after the initial planning activities. The number of items in a batch, and the number of processes in a product or service, should be between three and six.

Teams should be given a range of technical documentation (such as engineering drawings, production plans and specifications) prior to the manufacture of a batch of an engineered product or the delivery of a batch of an engineering service. Materials can be prepared and engineering equipment can be laid out prior to team activities, but each learner must set up and undertake at least one engineering process.

For Distinction standard, learners will consistently demonstrate at least one of the following traits during the planning and manufacturing or service activities: forward thinking, adaptability or initiative. For example, learners may respond to opportunities as they arise by convincing the team to adopt a more efficient approach to the manufacturing or service activities, or a different approach if a lack of equipment or resources demands it, or they may adapt to circumstances quickly by providing feedback to team members or by coaching others who are struggling with an activity or process. Learners may also prove their capability to adapt a process and/or machines to manufacture quantities of a product, for example by setting stops or by using simple techniques to process components at the same time. Similar approaches could be used in the delivery of a batch of an engineering service.

Learners will show their ability to objectively review team targets at suitable points and reach agreements with other team members as to an appropriate way forward given current progress.

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

For Merit standard, learners will demonstrate an active role in making decisions concerning the allocation of roles and responsibilities, time planning and setting team targets, for example by explicitly taking into account the preferences and perceived strengths of team members.

Learners will produce a risk assessment, which will be laid out on an appropriate industry-standard template and will include detailed attention to all five steps, for example clear identification of all significant hazards, who might be harmed and how, current precautions in place, further control measures needed and a suitable time period until review.

Learners will interpret technical documentation to set up safely and effectively at least one engineering process, so that others in the team could also carry out the process with minimal explanation required.

During the delivery of manufacturing or service processes, learners will show that they can work effectively as a team member and as a team leader to make effective progress towards team targets. For example, they will modify their approach based on feedback from peers and will generate a progress log to allow team members to quickly review progress.

Overall, the evidence will be clear, but some parts of it may be presented in an inconsistent fashion, making it more difficult for a third party to understand.

For Pass standard, learners will manage their contribution to making decisions concerning the allocation of roles and responsibilities, time planning and setting team targets. These activities will be completed as a minimum to set up and organise the team to manufacture a batch of an engineered product or to deliver a batch of an engineered service.

It will be essential to ensure that each team member has clear responsibilities and that everyone makes a contribution to the end result during the manufacture of a batch of an engineered product or the delivery of a batch of an engineering service. All individual team members must be clear about who is responsible and accountable for each aspect of the work, and team targets should be set and reviewed. To facilitate this, each team must carry out a series of meetings both prior to and during the manufacture of a batch of an engineered product or the delivery of a batch of an engineering service. Each member of the team must produce their own evidence against the assessment criteria, as evidence cannot be shared.

Learners will produce their own risk assessment to show how health and safety is managed in the engineering workplace, for at least one engineering process to be used when manufacturing the engineered product or when delivering the engineering service. The risk assessment should consider the most significant hazards with details of suitable control measures and be laid out on an appropriate industry-standard template. It will be appropriate, but may lack detail. For example, it may focus on the more obvious hazards and control measures, including those already in place.

Learners will also interpret technical documentation, including a production plan and an engineering drawing given to them, to set up safely at least one engineering process, so that they can carry out the process in a consistent manner.

During the delivery of manufacturing or service processes, learners will show that they can act independently as a team member and as a team leader to make progress towards team targets, although learners may demonstrate some reluctance to adapt to changing circumstances. The products or services delivered by the team do not have to be accurate and do not need to be tested for functionality, but teams must keep quality records. For example, the dimensions of a hole would be checked for conformance against the technical documentation and notes would be made on the outcome of the quality check. Also, teams do not need to rework any non-conforming product or service outcomes.

Overall, the evidence will be logically structured but may be imprecise and basic in some parts, meaning that only a third party with technical knowledge can understand aspects of it.

Links to other units

Learners should build on their knowledge of engineering approaches and their applications from *Unit 1: Mechanical Principles* and *Unit 57: Electrical and Electronic Principles*.

Opportunities to develop transferable employability skills

Learners will have the opportunities to develop the following transferable skills in the completion and assessment of this unit.

- Learners will use formal written documentation to present research findings from intensive investigations into given topics or themes.
- Learners will be able to use appropriate computer aided design (CAD) packages to create two dimensional (2D) drawings using a range of industrial standards and drawings conventions.
- Learners will take part in structured practical tasks and be able to complete a range of prescribed activities.
- Learners will be able to work safely in an engineering environment and ensure that themselves, and others around them are safe, when completing engineering operations and maintenance procedures.
- Independent tracking and monitoring of project work as it develops.

Unit 3: Product Design and Manufacture in Engineering

Level: 3
Unit type: Internal set assignment
Guided learning hours: 120

Unit in brief

Learners will explore engineering product design and manufacturing processes, and will complete activities that consider function, sustainability, materials, form and other factors.

Unit introduction

Engineering products are part of our daily lives, from aircraft to the smallest electronic circuits found in medical devices. Engineering products are designed as a result of the identification of a need or opportunity, and then engineers use creative skills and technical knowledge to devise and deliver a new design or improvements to an existing design. For example, advances in the development of fuels led to the first internal combustion engine, and engineers have been improving its design ever since.

In this unit, you will examine what triggers changes in the design of engineering products and the typical challenges that engineers face, such as designing out safety risks. You will learn how material properties and manufacturing processes impact on the design of an engineering product. You will also use an iterative process to develop a design for an engineering product by interpreting a brief, producing initial ideas and then communicating and justifying your suggested solution. You will draw on your learning from across your programme to complete the assessment tasks.

It is important that engineers use creative and technical knowledge, understanding and skills to transform ideas into viable products, and that they understand the critical importance of this activity in ensuring that products are both safe and effective. This unit will help prepare you for an engineering apprenticeship, engineering courses in higher education and for technician-level roles in a variety of engineering sectors.

Assessment

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

Learning aims

In this unit you will:

A Explore design triggers, challenges, constraints, opportunities and operational requirements

B Use an iterative process to develop ideas and a modified product design

C Generate technical justifications and validations for the design solution.

Content

Learning aim A: Explore design triggers, challenges, constraints, opportunities and operational requirements

A1 Design triggers

The triggers that stimulate engineering design activity, including:

- market pull/technology push (product and process)
- demand
- profitability
- innovation
- market research
- product/process performance issues
- sustainability (carbon footprint)
- designing out risk.

A2 Design challenges

Commercial-, regulatory- or public policy-based trends that challenge current technology or design to be more efficient and sustainable, including:

- reduction of energy wasted during design of an engineered product
- reduction of energy wasted during operation of an engineered product
- reduction of physical dimensions
- reduction of product mass
- increase in component efficiency
- energy recovery features
- reduced product life cycle costs (financial and non-financial)
- integration of different power sources for vehicles
- reduced use of resources in high-value manufacturing
- sustainability issues throughout the product life-cycle (raw materials, manufacture, packaging and distribution, use and reuse, end of life).

A3 Equipment level and system level constraints and opportunities

Factors that place limitations and offer opportunities at equipment level on the design of engineering products, including:

- reasons for selecting different solutions for equipment interfaces (mechanical, electrical, hydraulic, software)
- systems integration compromises (cooling, location for optimum equipment performance, bonding, centre of gravity, electrical and electronic compatibility)
- equipment product design specification (PDS) (shortcomings absorbed at system level, electromagnetic compatibility (EMC), mass, cooling)
- cost-effective manufacture (capital outlay, use of tooling, set-up cost)
- designing out risk for individual employees and customers.

A4 Design for a customer

Meeting customer needs during engineering design activity, including:

- types of customer (internal, external)
- product and service requirements (performance specifications, compliance to operating standards, manufacturing quantities, reliability/product support, product life cycle, usability, anthropometrics)
- product design specification/criteria (cost, quantity, maintenance, finish, materials, weight, aesthetics, product life cycle, sustainability, carbon footprint, reliability, safety, testing, ergonomics, usability, competition, market, manufacturing facility, manufacturing constraints, manufacturing processes)
- commercial protection (patents, registration, copyright, trademarks).

A5 Regulatory constraints and opportunities

Regulatory factors that place limitations and opportunities on the design of engineering products, including:

- legislation, standards, codes of practice, national and international certification requirements
- environmental constraints (sustainability, carbon footprint, product life cycle)
- health and safety, security (product and process).

A6 Market analysis

Engineering goals in terms of marketing when designing an engineering product, including:

- unique selling point (USP)
- benefits and improved features of the design
- obsolescence.

A7 Performance analysis

Engineering goals in terms of performance when designing an engineering product, including:

- product form
- product functionality
- technical considerations
- choice of materials and components
- environmental sustainability (impact, carbon footprint, ensuring the design allows the product to be manufacturing sustainable)
- interactions with other areas/components
- likelihood of failure or wear.

A8 Manufacturing analysis

Engineering goals in terms of manufacturing when designing an engineering product, including:

- processes for manufacturing/assembly
- manufacturing requirements
- quality indicators
- environmental sustainability (impact, carbon footprint)
- design for manufacture.

A9 Statistical methods

Statistical techniques as applied to engineering problems/design activity, including:

- statistical measurement (discrete/continuous, mean, median, mode, variance)
- data handling and graphical representation (bar chart, pie chart, frequency table, histogram, cumulative frequency diagram or graph).

Learning aim B: Use an iterative process to develop ideas and a modified product design

B1 Design proposals

Initial and developed propositions to improve an engineering product, including:

- technical design criteria
- idea generation (context, creativity, range)
- initial design ideas (fitness for purpose, refinements, recognition of constraints)
- developed design idea (aesthetics, ergonomics, sizes, mechanical and electronic principles, material requirements, manufacturing processes, assembly arrangements, cost estimations, factor of safety, safety, selection procedures for bought out components)
- use of information sources.

B2 Communicating designs

Communication of an initial and a developed proposition to improve an engineering product, including:

- freehand sketching and diagrams (2D and 3D, illustrations, technical)
- graphical techniques (charts, keys, shading, symbols, conventions)
- written skills (annotation, technical language, interpreting results)
- documentation (detail and assembly orthographic projections, specifications, parts list, materials list, production plan, circuit/block diagrams, flow chart, design log).

B3 Iterative development process

Using an iterative process to improve an engineering product, including:

- refining a task or process (analysing, adapting, enhancing)
- cyclic process (logical non-linear approach, focus on product design specification/criteria).

B4 Material properties

Properties, modes of failure, protection and lubrication of engineering materials and components that impact on their selection when designing an engineering product, including:

- mechanical properties
- physical properties
- thermal properties
- electrical and magnetic properties
- behaviour of advanced materials (bio materials, smart alloys, nanoengineered materials)
- modes of failure
- surface treatments and coating
- lubrication (purposes, regimes).

B5 Mechanical power transmission

Characteristics of an engineering system that makes use of forces and movement that impacts on mechanical power transmission component selection when designing an engineering product, including:

- linkages (types, mechanical advantage, examples from nature)
- mechanical motion (linear, rotary, reciprocating, oscillating)
- power sources (mechanical, electrical, energy from nature)
- control of power transmission (sensors, actuators, servomotors).

B6 Manufacturing processes

Characteristics and effects of manufacturing processes that impact on the selection of engineering materials and components when designing an engineering product, including:

- processes for metals (additive, moulding, machining, forming, casting, powder metallurgy, joining, assembly)
- processes for polymers (additive, casting, moulding, extrusion, thermoforming)
- processes for ceramics (additive, casting, forming)
- processes for composites (layup, moulding, automated tow placement)
- effects of processing (recrystallisation, grain structure, alloying elements, material combinations, process parameters)
- scales of manufacture (one-off, small batch, large batch, mass, continuous).

Learning aim C: Generate technical justifications and validations for the design solution

C1 Technical justifications and validating designs

Rationalise choices made when generating a developed proposition to improve an engineering product, including:

- objective referencing against product design specification/criteria
- objective referencing against weighted matrix
- indirect benefits and opportunities
- balancing improved features and opportunities with constraints and limitations (aspects that cannot be redesigned, cost-benefit analysis, environmental benefits, health and safety risks, product life cycle considerations)
- design for manufacturing
- further opportunities/modifications (technology-led adaptations).

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Explore design triggers, challenges, constraints, opportunities and operational requirements		
A.P1 Interpret the numerical data from the client brief into a set of partially valid findings. A.P2 Interpret the client brief into some appropriate requirements and opportunities or constraints. A.P3 Interpret the brief into some appropriate health and safety factors and sustainability considerations.	A.M1 Interpret the numerical data from the client brief into a set of mainly valid and accurate findings. A.M2 Interpret the client brief into a mostly cohesive set of appropriate product requirements, opportunities, constraints, health and safety factors and sustainability considerations.	A.D1 Interpret the client brief into a comprehensive and mostly justifiable set of requirements, opportunities, constraints, health and safety factors and sustainability considerations that should provide for enhanced product performance.

Cont.

Pass	Merit	Distinction
Learning aim B: Use an iterative process to develop ideas and a modified product design		
B.P4 Produce a range of design ideas, with some differences in form, that addresses some aspects of the client brief. B.P5 Communicate the design ideas using simplistic sketches and annotation with limited reference to existing products. B.P6 Produce a design solution that shows a variation in form and addresses some aspects of the client brief. B.P7 Communicate the design solution so that a competent third party could understand its purpose. B.P8 Select, from a limited investigation of options, suitable materials for the design solution that meet some of the requirements of the client brief. B.P9 Select, from a limited investigation of options, suitable manufacturing processes for the design solution that meet some of the requirements of the client brief.	B.M3 Produce a range of mostly feasible design ideas, with some differences in form and approach, that addresses most aspects of the client brief. B.M4 Communicate the design ideas using easy to understand sketches and annotation with some reference to existing products. B.M5 Produce an improved design solution with a clear variation in form and approach that is communicated so a competent third party could interpret how to manufacture it. B.M6 Justify, from an investigation of options, the selection of materials and manufacturing processes for the design solution that meet most of the requirements of the client brief.	B.D2 Produce a range of mostly clear, feasible and fit-for-purpose design ideas, with differences in form and approach, that comprehensively addresses the client brief, showing suitable reference to existing products. B.D3 Produce a design solution that is optimised, with a justified variation in form and approach, that is communicated concisely and with clarity so that a competent third party could effectively interpret how to manufacture it. B.D4 Optimise the selection of materials and manufacturing process for the design solution that meets the requirements of the brief.

Cont.

Pass	Merit	Distinction
Learning aim C: Generate technical justifications and validations for the design solution		
C.P10 Provide a partial rationale for why the design solution should be more effective than the original product. C.P11 Provide an appraisal of the design solution that considers some features, limitations, constraints and further opportunities.	C.M7 Provide a clear rationale for why the design solution should be more effective than the original product. C.M8 Provide a clear appraisal of the design solution that considers features, limitations, constraints and further opportunities.	C.D5 Provide a justified rationale for why the design solution is more effective than the original product, through a balanced appraisal of features, limitations, constraints and further opportunities.

Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners. Learners will be required to use design processes to develop a product proposal.

Learners' work will be submitted in the form of a completed assignment, which will be assessed by centre staff using the assessment criteria in this unit.

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to engineering design information from the internet and to printed resources.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners must use their interpretation of the numerical data to articulate how the results could be used when designing an enhanced product. The interpretation of the client brief will cover the full range of issues and will be evaluative and feed forward, leading to operational requirements that will facilitate the generation of a range of design ideas that are different in both form and approach, and a clear enhancement on the original product.

For Merit standard, learners must carry out some accurate calculations based on the numerical data in the client brief and state some sensible conclusions. The interpretation of the client brief will cover most of the issues and will be accurate, leading to operational requirements that will facilitate the generation of a range of design ideas that are an improvement on the original product.

For Pass standard, learners must carry out some calculations based on the numerical data in the client brief and state some subsequent conclusions, which may not be entirely valid or accurate. The interpretation of the client brief will cover a range of issues but may include statements that directly use the wording in the brief, leading to operational requirements that are limited in scope and/or non-contextual, and will facilitate the generation of design ideas that may be similar to the original product and/or each other.

Learning aim B

For Distinction standard, the design ideas will be different in both form and approach as they will include a range of adaptations that are major improvements when compared to the original product and the client brief, and they will appropriately utilise suitable features of existing products. The design ideas will be communicated using sketches and annotations that are clear and detailed. Learners will fully justify their choice of the most appropriate design idea and then develop it into a safe and optimised design solution, using a comprehensive range of relevant formal documentation (including technical drawings) to communicate it effectively. The design solution will also include clear and concise annotation which would allow a competent third party to effectively interpret how to manufacture it, and the use of technical terminology will be accurate and extensive throughout. The annotation will include accurate reasons for the choice of materials and manufacturing processes selected for the design solution and will show that the learner discounted several other options because those chosen were the most suitable given the context.

For Merit standard, the design ideas will be different in both form and approach, and will include some adaptations that are clear improvements when compared to the original product and the client brief, and they will utilise some features from existing products. The design ideas will be communicated using sketches and annotations that are straightforward to understand. Learners will explain their choice of design idea, which will be the most appropriate, and then develop it into an improved design solution that is safe, using a suitable range of formal documentation (including drawings) to communicate it. The design solution will also include sufficient annotation to allow a competent third party to interpret how to manufacture it, by making some assumptions, and the use of technical terminology will be accurate. The annotation will include sensible and justifiable reasons for the choice of materials and manufacturing processes selected for the design solution, with some reference to others that were not chosen and why.

For Pass standard, the design ideas will show some differences in form and will include adaptations that are minor improvements when compared to the original product and the client brief. They will reference the features of existing products, but this may be implicit. The design ideas will be communicated using simplistic sketches and annotations but they will be understandable. Learners will state their choice of design idea, which may not be the most appropriate, and then develop it into a practical and safe design solution, using some formal documentation (including sketches) to communicate it. The design solution will also include annotation that would allow a competent third party to understand it, and the use of technical terminology will be limited but mainly accurate. The annotation will include some sensible reasons for the choice of materials and manufacturing processes stated for the solution but those chosen may be generic and may lack specificity to the context.

Learning aim C

For Distinction standard, learners will generate an objective rationale that justifies why the design solution is more effective than the original product by directly referencing the full range of operational requirements (from Activity 1) and the client brief. The appraisal will be both evaluative and contextual, and will cover, in an explicit and consistent fashion, the full range of summary judgements and validations.

For Merit standard, learners will generate a rationale that gives clear and accurate reasons why the design solution is more effective than the original product by referencing most aspects of the client brief and the operational requirements (from Activity 1), but the statements generated may not always be objective. The appraisal will be accurate and contextual and will cover the full range of summary judgements and validations, but it may be inconsistent in places.

For Pass standard, learners will generate a rationale that gives some reasons why the design solution is more effective than the original product by referencing some aspects of the client brief and/or the operational requirements (from Activity 1), but the statements generated may not be entirely valid or accurate. The appraisal will provide some clear summary judgements and validations, but it may focus more on the perceived successes, and less on the possible ongoing issues and/or future opportunities related to the design solution.

Assessment controls

Time: the assignment must be completed in the stated time for the assignment.

Invigilation: learners should be invigilated and on centre premises when completing the assignment.

Resources: resources and learner work should be kept securely in the centre between assessment periods.

Research: learners may need to research their local environment to collect data to support their response. If this is the case, they are permitted to take notes and bring them back to the centre. Research time will be accounted for in the time requirement for the assignment.

Links to other units

This mandatory unit links to most other units in the suite of qualifications, including:

- Unit 1: Mechanical Principles
- Unit 2: Delivery of Engineering Processes Safely as a Team
- Unit 39: Modern Manufacturing Systems
- Unit 57: Electrical and Electronic Principles.

Opportunities to develop transferable employability skills

Learners will have the opportunities to develop the following transferable skills in the completion and assessment of this unit.

- Learners will be able to conduct thorough investigations and examinations of given themes and topics.
- Learners will use formal written documentation to present research findings from intensive investigations of given topics or themes. They will be able to organise and prioritise their study time when working towards an externally-assessed examination.
- Learners will become familiar with and develop their skills regarding iterative design.

Unit 39: Modern Manufacturing Systems

Level: 3
Unit type: Internal
Guided learning hours: 60

Unit in brief

Learners will investigate the principles of processing systems used in manufacturing and how operations are organised to make the most efficient use of time, materials and equipment.

Unit introduction

One of the key drivers for business success in manufacturing organisations is how operations are organised and how they respond to economic, social and technological change. It is vital that appropriate manufacturing systems and processing methods are employed to manufacture products safely, sustainably and cost-effectively, and that these systems and methods are reviewed and improved regularly. Organisations that have embraced business improvement techniques, such as Lean, have found them to be transformative, enabling increased efficiency and profitability across their organisations.

You will study the activities controlled by manufacturing operations and how the nature and performance of different areas may be influenced by current and future social and technological trends. You will examine how factory layouts are structured and organised and how the passage of a product through a factory is coordinated. Lastly, you will investigate Lean tools and improvement techniques before applying them to a manufacturing simulation to see their potential impact first hand.

All manufacturing industries, including aerospace, automotive, food, rail, biomedical and chemical, employ manufacturing engineers. This unit will help to prepare you for employment, for example as a manufacturing technician, for a traineeship/apprenticeship or entry to higher education.

Learning aims

In this unit you will:

A Understand the functions of manufacturing operations and factors influencing their success

B Examine process systems that are commonly used in the manufacturing industry

C Investigate the principles of Lean manufacturing and how these influence productivity.

Content

Learning aim A: Understand the functions of manufacturing operations and factors influencing their success

A1 Manufacturing operations

- The operations function of a manufacturing organisation is responsible for all aspects of the manufacture and delivery of products and/or services, including:
  - health and safety, e.g. manage statutory requirements such as laws and regulations on safety in working environments, health in working environments, risk assessment, hazardous substances, safe electrical equipment and tools
  - environmental protection measures, e.g. manage statutory requirements such as laws and regulations on climate change, waste, hazardous substances, sustainable uses of land and sea
  - manufacturing processes, e.g. assembly, automated processes (computer-aided manufacture (CAM), computer numerical control (CNC)), machining, fabrication
  - maintenance, e.g. preventative maintenance, servicing, breakdown recovery
  - warehousing, e.g. storage and organisation of raw materials and finished goods
  - quality management, e.g. inspection, quality control, quality assurance
  - logistics, e.g. shipping and distribution of finished goods to customers.
- Other factors that significantly influence manufacturing operations:
  - product design and development, e.g. innovation, design for manufacture, creation of new and modified products to fulfil customer needs, product or service sustainability
  - human resources, e.g. recruitment and staff training.

A2 Performance objectives in manufacturing operations

Performance in manufacturing operations is influenced by many factors:

- health and safety, to include
  - prevention of accidents, near misses and other unplanned incidents
  - managing occupational health through good process design to eliminate long-term conditions, e.g. repetitive strain injury, hearing loss
- quality, to include
  - the role of quality management in ensuring external customer satisfaction by providing products to the required standard on time
  - increasing internal process efficiency through elimination of waste
- lead times, to include
  - gaining competitive advantage by having short lead times from receipt of sales order to external customer delivery
  - limitations caused by internal processes and component manufacturing lead times and how these might be reduced
- dependability, to include
  - achieving on time delivery of products to external customers by avoiding unplanned events that may disrupt and delay the process, e.g. accidents, poor supplier on time delivery performance, machine breakdowns

- flexibility, to include
  - reducing time to market for new products, e.g. rapid prototyping, computer-aided design (CAD), CAM, design for manufacture
  - maintaining product mix flexibility to allow the manufacture of a wide range of products to match customer requirements, e.g. fast changeover time
  - maintaining volume flexibility to allow manufacturing capacity to match demand
- sustainability and environmental, to include:
  - using energy and material resources efficiently, minimising waste to reduce unsustainable consumption
  - reducing dependence on expensive or hazardous materials through innovative use of greener alternatives
  - increasing sales by meeting customer social and environmental needs
  - contributing to 'net zero'/cutting 'greenhouse gas' emissions
- costs, to include:
  - low scrap rate and low rework rate driven by a commitment to quality
  - reducing work in progress (WIP) inventory levels by fast processes with short lead times
  - reducing unplanned costs by developing high dependability processes
  - reducing wasted time and/or capacity through increased flexibility.

A3 Future trends influencing manufacturing operations

Manufacturing operations may be influenced by the following future trends, innovations and sustainability considerations, including:

- additive manufacturing (AM) may replace subtractive manufacturing processes
- energy security, e.g. the impact of moving away from fossil fuels
- environmental and 'right to repair' considerations, e.g. choosing between simple materials/assemblies that are easily repaired or recycled and complex material combinations (such as fibre composites) that reduce unsustainable energy consumption
- materials technology, e.g. the impact of competitive sport or defence on the development of innovative materials and manufacturing techniques
- manufacturing on demand, e.g. the technologies that must be in place to allow one-off customised products to be manufactured quickly
- robotics and automation, e.g. the impact of making robots increasingly aware of their surroundings and increasing their autonomy
- Virtual Product Creation (VPC), e.g. the impact of modelling complete complex systems such as aircraft prior to manufacture.

Learning aim B: Examine process systems that are commonly used in the manufacturing industry

B1 Process types and typical industrial applications

Principles, volume-variety characteristics and typical industrial applications of manufacturing process types

- Project processes:
  - characteristics include – usually one-off (very low volume), usually discrete, dedicated resources, high complexity, high variety, long timescales, long intervals between projects
  - typical applications, e.g. ships, oil rigs and tunnelling machines.

- Jobbing processes:
  - characteristics include – often one-off (low volume), high variety, high flexibility, highly skilled workforce, general purpose tools and equipment, low set-up cost
  - typical applications, e.g. bespoke furniture, custom motorcycles.
- Batch processes:
  - characteristics include – small to large batch (low to medium volume), limited variety, skilled workforce, flexible, some specialist tools and equipment
  - typical applications, e.g. clothing, automotive components.
- Mass processes:
  - characteristics include – mass (medium to high volume), low variety and flexibility, skilled workforce, specialist tools and automated equipment, high set-up costs
  - typical applications, e.g. consumer electronics, kitchen and cleaning appliances.
- Continuous processes:
  - characteristics include – continuous (high volume), very low variety, low skilled workforce, little or no flexibility, specialised highly automated equipment, high set-up costs
  - typical applications, e.g. petrochemicals, paper, steel, paper clips.

B2 Manufacturing layout types

Principles, characteristics and typical applications of manufacturing layout types and how these relate to process types:

- fixed layouts where transformed resources are in a fixed position, meaning transforming resources have to flow through the operation, e.g. shipbuilding where the product is too large to move
- process layouts that are dominated by the requirements or physical constraints of the transforming resources, e.g. a large powder coating plant may get optimal use if all coated components pass through it
- product layouts are dominated by the requirements of the transformed resources that flow along a line of transforming resources, e.g. car assembly plants
- cellular layouts where transformed resources are moved between cells with each cell completing one stage of the process, e.g. automotive component manufacture
- mixed or hybrid layouts combine elements of some or all of the basic types.

B3 Characteristics of effective system layout

- Safety to include fire exits, clear gangways, emergency equipment, controlled access to dangerous areas.
- Minimising length of flow to reduce distance travelled by transformed resources.
- Clearly visible signage, floor marking and barriers.
- Facilities for staff welfare, to include ventilation, lighting, noise control, amenities.
- Effective communications, to include location of supervisors and IT systems.
- Effective accessibility, to include ensuring access for large machinery during installation, sufficient space for servicing and maintenance.

- Efficient use of available space, including above and below manufacturing areas.
- Flexibility to accommodate operational change and expansion.
- Consequences of ineffective system layout, e.g. inefficient flow of materials, build-up of WIP, poor flexibility, wasted time, high cost.

B4 Manufacturing documentation

Documentation commonly used to control and coordinate manufacturing, including:

- work order to initiate manufacture stating part number, quantity and completion date
- routing cards to communicate the required process sequencing (route through the factory)
- materials lists to communicate component or raw material part numbers and quantity requirements
- stores requisitions used to authorise movement of required components or raw materials to work centres, e.g. a machine or workstation
- manufacturing instructions detailing standardised process methods
- visual aids, e.g. single piece engineering drawings, assembly drawings, circuit diagrams, photographs, approved sample used to exemplify the required standard.

Learning aim C: Investigate the principles of Lean manufacturing and how these influence productivity

C1 The Lean philosophy

- The aim of Lean is to meet demand instantaneously, with perfect quality and no waste.
- Characteristics of Lean in contrast to traditional manufacturing, to include:
  - goods are manufactured to exactly match customer orders, no forecast based finished goods inventory is held
  - short lead times enable rapid response to variation in demand
  - WIP and inventory buffers are kept to an absolute minimum
  - a culture of continuous improvement in all is encouraged from the top down
  - tasks across the business are performed consistently in the same way and developments in best practice are shared and implemented universally
  - defects are eliminated in all processes by identifying and rectifying the root cause
  - overall costs are reduced through increased efficiency, reduced space requirements and increased stock turns (high stock turns reduce the quantity of inventory held).

C2 Key elements of Lean

- Eliminating waste by the reduction of non-value added activities, to include: overproduction, waiting time, transport of materials, inappropriate or inefficient manufacturing processes, WIP inventory and stock items, unnecessary transportation or handling and defect associated waste, e.g. rework, scrap.
- Adopting team approach, to include: team problem solving, multi-skilling to allow job rotation and flexibility, encouraging process 'ownership' and responsibility and enriching roles, e.g. include maintenance and setting tasks in operator jobs.

- Continuous improvement, to include: encouraging a culture of innovation, managing change and process refinement.
- Improving quality by implementing strategies, including: quality control (QC), quality assurance (QA), total quality management (TQM).
- Increasing the dependability of internal processes and external suppliers.
- Increasing manufacturing flexibility in terms of both product mix and volume.

C3 Lean tools and methods

- Lean production systems:
  - awareness of common production systems, to include Toyota® Production System (TPS), Ford® Production System (FPS), Six Sigma.
- Widely implemented tools and methods used in Lean operations, to include:
  - standardised work practices to provide documented procedures of best practice that build in consistency and reduce process variation
  - design for manufacture to ensure optimal use of materials and processes
  - total productive maintenance (TPM) to eliminate unplanned breakdowns
  - bottleneck analysis to identify processes limiting overall throughput
  - just-in-time (JIT) to pull parts through manufacture based on customer demand, instead of pushing them through based on a forecast
  - Kanban (pull system) automatic stock replenishment systems
  - 5S to organise work areas (sort, set in order, shine, standardise, sustain)
  - continuous flow to enable smooth flow of WIP between stages without buffers
  - Kaizen (continuous improvement) to improve processes over time based on suggestions from employees working together
  - Poka-Yoke (error proofing) to incorporate error detection and/or prevention into process design
  - Takt Time to define the pace of manufacturing to match customer demand
  - set-up reduction (SUR)/Single-Minute Exchange of Die (SMED) to minimise the time required between finishing one batch of a product and completing first good product of the next batch, to include:
    - use of standard fixtures, jigs and other tooling to improve interchangeability
    - pre-setting tooling to minimise or eliminate set-up time
    - improving product handling devices to aid loading and unloading tools and dies, e.g. rollers conveyors, cranes, trolleys.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the functions of manufacturing operations and factors influencing their success		A.D1 Evaluate, using language that is technically correct, the functions of and factors affecting the performance of manufacturing operations and how these might change in the future.
A.P1 Explain the functions of and factors affecting the performance of manufacturing operations and how these might change in the future.	A.M1 Analyse the functions of and factors affecting the performance of manufacturing operations and how these might change in the future.	
Learning aim B: Examine process systems that are commonly used in the manufacturing industry		B.D1 Evaluate, using contrasting product examples, the selection of manufacturing process types, layouts and documentation used, suggesting improvements where appropriate.
B.P2 Explain, using contrasting product examples, the principles and characteristics of different manufacturing process types. B.P3 Explain, using contrasting product examples, the principles and characteristics of different manufacturing layout types. B.P4 Explain, using contrasting product examples, the importance and use of manufacturing documentation.	B.M2 Analyse, using contrasting product examples, the selection of manufacturing process types, layout types and documentation used.	

Cont.

Pass	Merit	Distinction
Learning aim C: Investigate the principles of Lean manufacturing and how these influence productivity		
C.P5 Explain the key characteristics of Lean and the requirements needed to implement it successfully. C.P6 Explain how at least one Lean tool and/or method can be applied C.P7 Demonstrate effectively at least one of the key Lean tools, using a manufacturing simulation.	C.M3 Analyse how a range of Lean tools and/or methods relate back to the key characteristics of Lean. C.M4 Demonstrate effectively a range of the key Lean tools and/or methods, using a manufacturing simulation.	C.D3 Evaluate how a range of Lean tools and/or methods relate back to the key characteristics of Lean, including the effectiveness of a Lean manufacturing simulation.

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.M1, A.D1) could be assessed through a report on the functions contained in a manufacturing operation and factors affecting the performance of a manufacturing organisation. Learners must also investigate likely future trends affecting manufacturing organisations.

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.D2) could be assessed through a report justifying the type of manufacturing system used to manufacture contrasting products, which should include an explanation of all relevant documentation. Evidence should include diagrams and/or photographs to support an evaluation of the layout used. This would best be achieved in collaboration with an industrial partner or it could be based on case study materials.

Learning aim: C (C.P5, C.P6, C.P7, C.M3, C.M4, C.D3) could be assessed through a presentation outlining the principles of Lean and its application to transform a traditional manufacturing operation. Part of the presentation will include the delivery of an activity devised by learners that illustrates a range of the principles of Lean effectively by simulating how part of a manufacturing system might be improved.

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to case study materials on the functions of and performance factors in manufacturing operations and in the process systems. Ideally, these materials could be developed in collaboration with an industrial partner and be supported with industrial site visits.

A range of proprietary Lean simulation kits are available commercially, which would be useful, if not essential, in the delivery of this unit.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will provide a balanced evaluation of how a range of factors relate to and influence the performance of a manufacturing operation. For example, how increasing dependability will require changes in maintenance procedures to help prevent unscheduled breakdowns and action by health and safety management to help prevent accidents or incidents that might cause delays. Learners will come to a conclusion about which factor is likely to have the greatest impact on improving overall performance. For example, increased dependability is likely to be more important than flexibility where very large batches of products are manufactured. In addition, learners must also make a judgement regarding the importance of relevant social, economic or technological trends for a manufacturing operation by assessing whether their impact on performance will be significant in the future. For example, learners might consider the advantages and disadvantages of additive manufacturing (AM) when used as an alternative to die casting in the manufacture of engine components and justify an opinion on the likely uptake of this emerging technology in the automotive sector.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer. It will be logically structured and use correct technical engineering terms.

For Merit standard, learners will provide a detailed analysis of how a range of factors relate to and influence the performance of a manufacturing operation. For example, how increasing flexibility will require changes to manufacturing processes that might include reducing set-up times, providing additional training to develop a mobile, multi-skilled workforce that can be redeployed quickly to eliminate bottlenecks, and employing a cellular (U shaped or serpentine) process layout. In addition, learners must analyse the potential impact of a relevant social, economic or technological trend on the performance of a manufacturing operation and how the operation might change as a consequence. For example, the drive for more sustainable manufacturing is likely to affect the choice of processes used as manufacturers seek to use less energy, less material and generate less pollution, which may lead to a move away from subtractive towards additive manufacturing processes where possible.

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

For Pass standard, learners will provide a clear explanation of the importance of the functions in a manufacturing operation. For example, the role of maintenance is to maintain and repair equipment, human resources is to recruit and train the workforce. Learners must also explain the performance objectives of a manufacturing operation and suggest how these might be achieved. For example, how increasing flexibility allows quicker response to customer demand and how it might be improved by training multi-skilled staff. In addition, learners must explain how a manufacturing operation might change in response to relevant social, economic or technological trends over the next 20 years. For example, the drive for more sustainable manufacturing is likely to drive changes in many areas, including manufacturing processes, component design, materials, emissions and waste disposal.

Overall, the evidence will be logically structured. Evidence may be basic in parts, for example making general statements about changes to manufacturing operations without clearly explaining how these might be achieved, and may contain technical inaccuracies or omissions, such as the occasional use of non-technical language.

Learning aim B

For Distinction standard, learners will provide a balanced evaluation of how the characteristics of two contrasting products influenced the selection of appropriate process and layout types and the type, complexity and use of the documentation used to coordinate manufacture. In addition, they will explain why their use is justified or suggest potential improvements. For example, learners might use the Ford Focus and Morgan Classic Plus 4 as two contrasting products. They might explain that in the Morgan factory hard copies of engineering drawings are kept on the shop floor. Learners would evaluate the advantages and disadvantages of this system and suggest possible alternatives, such as using monitors or tablets to display drawings, and explain how this might improve efficiency, reliability and speed of manufacture.

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

For Merit standard, learners will provide a clear and detailed analysis of how the characteristics of two contrasting products influenced the selection of appropriate process and layout type for their manufacture. They will consider the complexity of the manufacturing processes involved, the volume required and wider issues such as the variety of products using the same manufacturing resources. For example, learners might use the Ford Focus and the Morgan Classic Plus 4 as two contrasting products where volume, cost and exclusivity are the main differentiators. The complex, automated, high-volume Ford plant will contrast significantly with the batch-oriented, highly skilled Morgan factory. Learners will also provide a detailed analysis of how the type, complexity and use of the documentation used to coordinate the manufacture of the contrasting products relates to the process type and layout in use and the complexity of the products being manufactured. For example, the complex products in the Ford plant require the coordinated delivery of raw materials via stores requisitions, sub-assemblies created via work orders from elsewhere in the factory and consumables such as screws and fixings taken from shop floor storage areas replenished using Kanban cards. This is generally far too complex to rely on a basic paper system and so computers and automated handling systems are used extensively to help coordinate stock movements.

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

For Pass standard, learners will clearly explain how the different manufacturing process types are applied in the manufacture of at least two contrasting products. Learners will also explain how manufacturing volume influences the process type selected. For example, learners might use the Ford Focus and the Morgan Classic Plus 4 as two contrasting products and explain how mass and batch process types are employed in their manufacture.

Learner evidence will clearly explain the arrangement of manufacturing resources and how the product being manufactured moves through them, using two contrasting products as examples. For example, they will explain how the Ford Focus plant and Morgan factory are laid out and how the chassis move through the facilities as they are built up into finished vehicles.

Learners' evidence will clearly explain the importance of documentation to coordinate the manufacture of at least two contrasting products. In particular, evidence will outline what the documentation is used to communicate and to whom, when and how it is issued and the activities triggered, coordinated and/or managed. For example, work orders are typically issued by manufacturing planners to shop floor supervisors to trigger the manufacture of a defined number of components by a certain date. They are issued in hard copy and remain with the product until it is completed.

Overall, the evidence may be basic in parts, for example in the explanation of the characteristics of a specific process type, and contain minor technical inaccuracies or omissions. For example, learners may fail to explain the importance and use of some of the information contained in the manufacturing paperwork.

Learning aim C

For Distinction standard, learners will provide a balanced evaluation of how a range of at least three Lean tools and/or methods relate back to the key characteristics of a Lean operation. In addition, they will evaluate how effective a range of at least three Lean tools and/or methods are in helping to achieve the key characteristics of Lean operations, referring in part to their experience of applying Lean tools and/or methods in a manufacturing simulation. Learners will form a clearly reasoned judgement on which of the tools and/or methods considered are able to make the most effective contribution to supporting the key characteristics of Lean.

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

For Merit standard, learners will analyse, in detail, how a range of at least three Lean tools and/or methods relate back to the key characteristics of a Lean operation. Each Lean tool and/or method should be explained in detail and learners will identify which problems they are designed to eliminate, the methodology involved in their use and their expected impact on the processes involved. Furthermore, learners will clearly link the outcomes of using the tools and/or methods to the principles of Lean operations. For example, a clear explanation of the application of set-up reduction methods will go on to explain how these will help achieve greater flexibility in manufacturing operations.

Learners will demonstrate a range of at least three Lean tools and/or methods effectively by applying them to one or more manufacturing simulations. The simulations must be of sufficient complexity to enable meaningful results to be seen, which in most cases will depend on the tools being applied. For example, a manufacturing simulation involving the assembly of a simple product could be used to demonstrate the effectiveness of Kanban and bottleneck analysis in improving flow and helping to synchronise manufacturing rate with demand. In addition, a set-up reduction simulation could be used to demonstrate the time saving possible when SMED (Single Minute Exchange of Die) methodologies are applied. Learners will provide evidence of how the simulation will be set up and controlled, the Lean tool and/or method being applied, the details of the problem(s) it is designed to eliminate, the expected outcome of the simulation and the actual outcome obtained.

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

For Pass standard, learners will clearly explain the key characteristics of Lean and how these might be implemented in practice. For example, one of the principles of Lean is to operate with short lead times. Learners should explain why this gives an operation a competitive advantage and then outline how it might be worked towards by implementing a specific Lean principle, such as improving flow to eliminate waiting time between process steps and so decrease overall production time.

Learners' evidence will clearly explain how Lean tools and/or methods might be implemented in a manufacturing environment. For example, learners might provide a detailed explanation of the 5S methodology, including details of the problem(s) it is designed to eliminate, the principles of 5S itself and how it might be implemented in a scenario based on a case study.

Learners' evidence will demonstrate at least one Lean tool effectively by applying it to a manufacturing simulation. The simulation must be of sufficient complexity to enable meaningful results to be seen, which in most cases will depend on the tools being applied. For example, a manufacturing simulation involving the assembly of a simple product could be used to demonstrate the effectiveness of Kanban pull systems in improving flow and helping to synchronise manufacturing rate with demand. Learners should provide evidence of how the simulation will be set up and controlled, the Lean tool and/or method being applied, the details of the problem(s) it is designed to eliminate, the expected outcome of the simulation and the actual outcome obtained.

Overall, learner evidence, including simulation results, will be logically structured and easy to follow. The evidence may be basic in parts, for example explanations may lack detail and contain minor technical inaccuracies relating to engineering terminology, such as in the use of the acronyms common in Lean.

Links to other units

This unit links to:

- Unit 2: Delivery of Engineering Processes Safely as a Team

Employer involvement

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

- guest speakers
- technical workshops involving staff from local world-class manufacturing organisations
- contribution of ideas to unit assignment/project materials.

Opportunities to develop transferable employability skills

Learners will have the opportunities to develop the following transferable skills in the completion and assessment of this unit.

- Research and analysis skills when reflecting on a given brief or task.
- Learners will use formal written skills to complete reports based on given themes or tasks. These reports will require learners to reflect and extrapolate future concepts and trends.
- Learners will use presentation software to develop presentations based upon given themes or tasks.

Unit 57: Electrical and Electronic Principles

Level: 3
Unit type: Internal set assignment
Guided learning hours: 60

Unit in brief

Learners develop the skills and knowledge required to solve engineering problems related to electricity and magnetism by applying mathematical and physical science principles.

Unit introduction

Modern life depends on engineers to develop, support and control the electrical and electronic products and systems that are all around us, for example communication systems, computers, electric vehicles and games consoles. To make a contribution as an engineer, you must be able to draw on an important range of principles developed by early engineering scientists, such as Faraday, Ohm and Edison.

There is an increasing demand for 'multi-skilled' engineers who can apply principles from several engineering disciplines to develop solutions to engineering problems. This unit will develop your mathematical and physical scientific knowledge and understanding to enable you to solve problems set in an engineering context. You will explore and apply the algebraic, trigonometric and statistical methods required to solve engineering problems. The electrical and electronic problems you will encounter cover static and direct current electricity, alternating current electricity and magnetism. You may apply the engineering principles you have learned to solve problems involving more than one of these topic areas.

This unit sits at the heart of the qualification and gives you a foundation to support you in any engineering technician role, a trainee role in engineering and progression to higher education.

Assessment

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

Learning aims

In this unit you will:

A Examine how algebraic, trigonometric and statistical mathematical methods can be used to solve engineering problems

B Explore engineering problems involving static and direct current electricity and circuits

C Explore magnetism and electromagnetic induction in engineering

D Explore engineering problems involving alternating current electricity and circuits.

Content

Learning aim A: Examine how algebraic, trigonometric and statistical mathematical methods can be used to solve engineering problems

Application of appropriate units. Application of rounding: decimal places and significant figures.

A1 Algebraic methods

- Solve, transpose and simplify equations.
- Routine methods:
  - Pythagoras' theorem
  - indices and logarithms
    - laws of indices $a^m \times a^n = a^{m+n}$
    - laws of logarithms $\log AB = \log A + \log B$
    - common logarithms (base 10), natural logarithms (base e).
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - indices and logarithms
    - laws of indices $a^m/a^n = a^{m-n}$, $(a^m)^n = a^{mn}$
    - laws of logarithms $\log A^n = n\log A$, $\log (A/B) = \log A - \log B$
    - application to problems involving exponential growth and decay
  - linear equations and straight line graphs
    - pair of simultaneous linear equations in two unknowns.

A2 Trigonometric methods

- Routine methods:
  - circular measure
    - radians, where 2π radians = 360°
    - conversion of radian measure to degree measure $\theta_{degrees} = \frac{360\,\theta_{radians}}{2\pi}$
    - conversion of degree measure to radian measure $\theta_{radians} = \frac{2\pi\,\theta_{degrees}}{360}$
  - triangular measurement
    - functions (sine, cosine and tangent)
    - sine/cosine wave over one complete cycle
    - values of the trigonometric ratios for angles between 0° and 360°
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - triangular measurement
    - graph of $\tan A$ as A varies from 0° and 360° and $\tan A = \sin A/\cos A$
    - periodic properties of the trigonometric functions
  - application of vectors
    - calculation of the phasor sum of two alternating currents
    - diagrammatic representation of vectors.

A3 Statistical methods

- Routine methods:
  - statistical methods
    - data represented by statistical diagrams: bar charts, pie charts, frequency distributions
    - class boundaries and class width
    - frequency tables
    - variables (discrete and continuous).
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - statistical methods
    - histogram (continuous and discrete variants)
    - cumulative frequency curves
    - statistical measurement: arithmetic mean, median, mode
    - discrete and grouped data.

Learning aim B: Examine engineering problems involving static and direct current electricity and circuits

Application of appropriate units. Application of rounding: decimal places and significant figures.

B1 Static and direct current electricity principles

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

- Routine methods:
  - conductance
  - conventional current flow
  - charge/electron flow ($I = q/t$)
  - voltage
  - resistors, including function, fixed, variable, values
  - capacitors – typical capacitance values and construction, including plates, dielectric materials and strength, flux density, permittivity.
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - Coulomb's law
  - electric field strength, $E = F/q$ or $E = v/d$ for uniform electric fields
  - factors affecting resistance, including
    - conductor length
    - cross-sectional area
    - resistivity
    - temperature coefficient of resistance
  - factors affecting capacitance, including plate spacing, plate area, permittivity.

B2 Direct current circuit theory

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

- Routine methods:
  - Ohm's law $I = V/R$
  - Power $P = IV$, $P = I^2R$, $P = V^2/R$
  - efficiency $(\eta) = P_{out}/ P_{in}$
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - Kirchhoff voltage and current laws voltage
  - $V = V_1 + V_2 + V_3$ or $\Sigma PD = \Sigma IR$, and current $I = I_1 + I_2 + I_3$
  - charge, voltage, capacitance and energy stored in capacitors
  - RC transients (capacitor/resistor), charge and discharge, including exponential growth and decay of voltage and current, and time constant $\tau = RC$
  - diodes, including forward and reverse bias characteristics
    - forward mode applications, including rectification, clamping, circuit/component protection
    - reverse mode applications, including Zener diode for voltage regulation.

B3 Direct current networks

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

- Routine methods:
  - DC power sources, including cells, batteries, stabilised power supply, photovoltaic cell/array and internal resistance
  - at least five resistors in series and parallel combinations.
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - DC circuits containing resistors and two power sources
  - DC power source with at least two capacitors connected (series, parallel, combination).

Learning aim C: Examine magnetism and electromagnetic induction in engineering

Application of appropriate units. Application of rounding: decimal places and significant figures.

C1 Magnetism

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

- Routine methods:
  - magnetic fields
    - flux density
    - magnetomotive force (mmf) and field strength (H), Fm = NI, H NI
    - permeability $\mu^0 = 4\pi \times 10^{-7}\ H/m$

- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - magnetic fields
    - B/H curves and loops
    - ferromagnetic materials
    - reluctance
    - magnetic screening
    - hysteresis.

C2 Electromagnetic induction

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

- Routine methods:
  - electromagnetic induction and applications
    - induced electromotive force (emf)
    - relationship between induced emf, magnetic field strength, number of conductor turns and rate of change of flux
    - relationship between number of turns, magnetic length, permeability, and inductance
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - electromagnetic induction and applications
    - eddy currents
    - principle of operation of electric motors and generators, including efficiency
    - self-inductance, including inductance of a coil, energy stored in an inductor, induced emf
    - mutual inductance (principals of transformer operation – step up/down, primary and secondary current and voltage ratios, including efficiency)
    - application of Faraday's and Lenz's laws.

Learning aim D: Examine engineering problems involving single-phase alternating current

Application of appropriate units. Application of rounding: decimal places and significant figures.

D1 Alternating current waveforms

Recall, perform procedures, demonstrate an understanding of and analyse information and systems involving the following.

- Routine methods:
  - waveform characteristics
    - sinusoidal and non-sinusoidal waveforms
    - amplitude, time period, frequency
  - instantaneous values
    - peak/peak-to-peak
    - peak voltage
    - form factor.

- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - waveform characteristics
    - sinusoidal and non-sinusoidal waveforms
    - amplitude, time period, frequency
  - instantaneous values
    - RMS voltage
    - form factor.

D2 Single-phase alternating current principles

- Routine methods:
  - determination of values using phasor and trigonometric representation of
    - alternating quantities
    - graphical addition of two sinusoidal voltages
    - reactance and impedance of pure R, L and C components.
- Non-routine methods involve the following topics and/or multiple steps to make connections:
  - phasor addition of two sinusoidal voltages
  - total impedance of an inductor in series with a resistance
  - total impedance of a capacitor in series with a resistance
  - rectification, including half wave, full wave.

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Examine how algebraic, trigonometric and statistical mathematical methods can be used to solve engineering problems</td><td rowspan="5">A.D1 Solve accurately routine and non-routine problems using algebraic and trigonometric methods.</td></tr>
<tr><td>A.P1 Solve given routine problems using algebraic methods.
A.P2 Solve given routine problems using trigonometric methods.
A.P3 Interpret and present statistical information related to engineering problems.</td><td>A.M1 Solve routine problems accurately and non-routine problems using both algebraic and trigonometric methods.</td></tr>
<tr><td colspan="2">Learning aim B: Examine engineering problems involving static and direct current electricity</td></tr>
<tr><td>B.P4 Solve routine problems that involve direct currents.
B.P5 Solve routine problems that involve direct current networks.</td><td>B.M2 Solve routine problems accurately and non-routine problems that involve direct current networks.</td></tr>
<tr><td colspan="2">Learning aim C: Examine magnetism and electromagnetic induction in engineering</td></tr>
<tr><td>C.P6 Solve routine problems that involve magnetism.
C.P7 Solve routine problems that involve electromagnetism.</td><td>C.M3 Solve routine problems accurately and non-routine problems that involve magnetism and electromagnetism.</td><td rowspan="3">BCD.D2 Solve accurately routine and non-routine problems using complex electrical/electronic methods.</td></tr>
<tr><td colspan="2">Learning aim D: Examine engineering problems involving single-phase alternating current</td></tr>
<tr><td>D.P8 Solve routine problems that involve alternating currents.</td><td>D.M4 Solve routine problems accurately and non-routine problems that involve alternating currents.</td></tr>
</table>

Essential information for assignments

This unit is assessed using a Pearson Set Assignment Brief. A set assignment must be used to assess learners. Learners will be required to interpret and use data and information relating to engineering scenarios. Learners' work will be submitted in the form of a completed assignment, which will be assessed by centre staff using the assessment criteria in this unit.

Further information for teachers and assessors

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners must show a full range of progressive steps when producing solutions to problems that that may include minimal errors such as those associated with transposition, rounding and standard form, particularly for the non-routine problems. They will demonstrate good use of methods, including a concise approach to reaching solutions. Working will be neat and well presented, and will follow a logical structure.

Learners will demonstrate an appropriate choice of units and, where necessary, accurate use of standard form. Solutions will be provided to an appropriate degree of precision and be presented in their simplest form. Learners may also include some evidence of checking answers and they will possibly make amendments as a result.

For Merit standard, learners must produce solutions for routine and non-routine problems. For routine problems, most working should be completed with accuracy, and will demonstrate correct use of appropriate methods.

For non-routine methods, learners may demonstrate some errors in their working, such as obvious omissions and transposition/rounding/conversion errors. Some inappropriate use of standard form is also likely, although where arithmetic errors have been made these are likely to be carried through in subsequent working.

For Pass standard, learners must show solutions that are logical in the choice of methods to be followed. Solutions to problems that involve routine methods are likely to involve some errors but will be followed through to a plausible solution. Use of standard form will not be evident or may be used inaccurately.

Learning aims B, C and D

For Distinction standard, learners must show a full range of progressive steps when producing concise solutions to complex for a range of mechanical engineering problems. They will interpret the information provided and then demonstrate good correct use of methods, including a concise approach to reaching solutions, although some minor errors may be present in working such as those associated with transposition, rounding and standard form for non-routine problems, some minor errors may be present in working. Learners will recognise links between different aspects of mechanical engineering problems and will produce solutions that follow a logical structure.

Learners will demonstrate an appropriate choice of units and, where necessary, accurate use of standard form. Solutions will be provided to an appropriate degree of precision and be presented in their simplest form. Learners may also include some evidence of checking answers and they will possibly make amendments as a result.

For Merit standard, learners must produce solutions to a range of static, dynamic and fluid engineering problems that involve both the use of routine and non-routine methods. For routine methods, most working will be completed with accuracy and learners will demonstrate correct use of appropriate methods to solve each type of problem.

For non-routine methods, learners may demonstrate some errors in their working, such as obvious omissions and transposition, rounding and conversion errors or taking approaches that are not obvious but which arrive at suitable solutions. Some inappropriate use of standard form is also likely, although where arithmetic errors have been made these are likely to be carried through in subsequent working.

For Pass standard, learners must show solutions to routine static, dynamic and fluid engineering problems that are logical in the choice of methods to be followed.

Solutions to routine problems are likely to include some errors but will be followed through to a plausible solution. Use of standard form will not be evident or may be used inaccurately.

Assessment controls

Time: the assignment must be completed in the stated time for the assignment.

Invigilation: learners should be invigilated and on centre premises when completing the assignment.

Resources: resources and learners' work should be kept securely in the centre between assessment periods.

Research: learners may need to research their local environment to collect data to support their response. If this is the case, they are permitted to take notes and bring them back to the centre. Research time will be accounted for in the time requirement for the assignment.

Links to other units

This unit links to:

- Unit 1: Mechanical Principles
- Unit 2: Delivery of Engineering Processes Safety as a Team
- Unit 3: Engineering Product Design and Manufacture
- Unit 4: Applied Commercial and Quality Principles in Engineering.

Opportunities to develop transferable employability skills

Centres may involve employers in the delivery of this unit if there opportunities to do this locally.

Unit 59: Battery Manufacturing

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers electric and hybrid vehicle batteries as well as battery manufacturing systems and processes. Learners will explore the range of batteries that have been developed and used in hybrid and electric vehicle applications and how they provide power for the vehicle relevant to its demands. Learners will review how batteries interact with vehicle systems in both hybrid and electric situations, how batteries interact with existing carbon fuel systems in hybrids and how the traditional mechanical systems are powered by the battery in an electric vehicle. Learners will look at the operation of common battery types and be able to describe the chemical reactions that occur to generate and store the needed electrical power.

The unit continues on to cover the manufacturing processes involved in the manufacture and assembly of battery cells, modules and packs. Learners will review the manufacturing processes that are involved in the creation of a variety of battery cell types. The manufacturing sequences will be explored, and the machinery needed to create the cells identified and studied. The unit progresses on to look at the way the cells are combined to create the individual battery modules needed to create the final battery packs. Learners will look at the construction processes needed to allow the correct power to flow from each cell and then each module. The links through busbar additions and power management circuits will be reviewed, together with the cleaning protocols needed to prevent damage or malfunction after each construction phase. The final assembly process for the battery packs, their framework and circuits will be understood. Throughout the unit learners will develop an understanding of the safety protocols needed in manufacturing and especially within the battery manufacturing environments.

Learning aims

In this unit you will:

A Know about batteries used in electric and hybrid vehicles

B Understand the operating principles of electric and hybrid vehicle batteries

C Explore electric and hybrid vehicle battery manufacturing

D Know about safe working practices when manufacturing electric and hybrid batteries.

Unit content

Learning aim A: Know about batteries used in electric and hybrid vehicles

A1 Battery types used in electric and hybrid vehicles in own region

- Battery types used in electric and hybrid vehicles:
  - battery type identification used for electric and hybrid vehicle manufactures, e.g.:
    - Toyota hybrid (Nickel-metal hydride),
    - Tesla (Lithium-Ion)
    - Jaguar electric vehicles (Lithium-ion)
  - identification of common batteries used, or have been developed for use, in electric and hybrid vehicles, e.g.:
    - alkaline
    - sodium-nickel chloride, sodium-sulphur
    - lithium-ion
  - battery power sizes, e.g. battery kWh and potential range of the vehicle
  - variety of electric vehicle manufacturers' warranties (vehicle and battery) set out in time and distance measurements, e.g.:
    - Jaguar
    - BMW
    - Hyundai.

A2 Interactions between the vehicle systems and the batteries

- An overview of the electrical systems in a hybrid vehicle that link to the low voltage (LV) and/or the high voltage (HV) systems, e.g.:
  - HV systems, e.g. drive systems, battery management controller, inverters, direct charging system
  - LV systems, traditional circuits, e.g. engine management, lighting, heating, power steering, DC charging systems
  - how the systems are charged, managed and how they co-exist within the vehicle.
- An overview of the electrical systems in an electric vehicle that require different voltage levels e.g.:
  - HV systems, e.g. direct drive system, battery and power management, regeneration systems
  - LV system identification, e.g. heating and air conditioning, electric brake system, power-assisted steering
  - LV systems: comparisons between hybrid and electric vehicle systems, different operating requirements, input variances, adaptions for operation and impacts e.g. heat pumps, liquid cooling systems, heat exchangers, servo-assisted to electronically controlled master cylinders.

Learning aim B: Understand the operating principles of electric and hybrid vehicle batteries

B1 Operating processes of different battery types used in electric/hybrid vehicles

- Working processes of electric and hybrid vehicle batteries:
  - battery types e.g. Alkaline (Ni-Cad, Ni-Fe, Ni-MH), Sodium-nickel chloride ($Na\text{-}NiCl_2$), Sodium-sulphur (Na-S), Lithium-ion (Li-ion)
  - construction of each battery type e.g. Alkaline (Ni-Cad, Ni-Fe, Ni-MH), Sodium-nickel chloride ($Na\text{-}NiCl_2$), Sodium-sulphur (Na-S), Lithium-ion (Li-ion)
  - working cycle of the different battery types, charging, discharging and storage of power e.g. Alkaline (Ni-Cad, Ni-Fe, Ni-MH), Sodium-nickel chloride ($Na\text{-}NiCl_2$), Sodium-sulphur (Na-S), Lithium-ion (Li-ion)
  - battery technical specifications for the following battery types; Alkaline (Ni-Cad, Ni-Fe, Ni-MH), Sodium-nickel chloride ($Na\text{-}NiCl_2$), Sodium-sulphur (Na-S), Lithium-ion (Li-ion)
  - battery operating specifications e.g. specific energy (Wh/kg), specific power (W/kg), amp-hour efficiency, operating temperature (^oC), self-discharge (%), life cycles to 80%, recharge time (h)
  - the impacts of the specifications on the battery when in use in the vehicle, vehicle users and potential battery life.

Learning aim C: Explore electric and hybrid vehicle battery manufacturing

C1 Battery cell construction process

- Anode and cathode chemical and material location and preparation.
- Component coating, e.g. anode material combination, cathode material combination.
- Drying phase: material drying and cooling.
- Electrode completion: e.g. ESD removal, cleaning, sizing, measurement of conformity, re-cleaning.
- Final shaping processes, e.g. cutting, slitting, cleaning, drying, anode and cathode shaping.
- Separator insertion.
- Pouch preparation and installation: cell tab connection, pouch insertion, partial sealing.
- Finishing processes, e.g. electrolyte addition, degassing and final sealing.
- End of line (EOL) and final testing procedures, e.g. charge and shipping voltages, loss rate, visual inspection.

C2 Battery module construction process

- Cell preparation: product identification e.g. barcode scanning; cleaning e.g. plasma, ionised air cleaning, isobutanol cleaning, surface treatment.
- Tab and connector shaping: tab trimming, tab bending, tape application and cell bending, foam application, glue application, cell testing e.g. polarity, weighing, quality vision, size checks.
- Frame installation (if needed) e.g. cleaning and taping.
- Stacking, e.g. compression pads, end plates, welding or fixings, compression.
- Busbar addition: fitment; parallel, series and series-parallel connections; tab attachments and welding.
- Welding checks: non-destructive testing, resistance testing.

- Printed circuit board and battery management unit installation.
- Case sealing and welding: thermal exchange plates, sealant addition, welding.

C3 Battery pack construction process

- The pack is designed depending on the vehicle it is being used in and the batteries that are being purchased for use, voltage requirements and location within the vehicle chassis.
- Insertion of the battery modules
- Interconnection of the individual battery modules
- Thermal and electric integration including - Busbar system, Battery management system, Cooling system, HV module, HV and LV connections
- Sealing and leaking testing
- Charging, flashing and thermal testing
- End of line testing.
- Connection and integration of the battery module to vehicle chassis and HV and LV systems

Learning aim D: Know about safe working practices when manufacturing electric and hybrid batteries

D1 Manufacturing safety protocols

- Risk assessment of manufacturing processes e.g. individual operation assessments, movement risk assessments, positional risk assessments.
- Specialist assessments for Control of Substances Hazardous to Health (COSHH) Regulations e.g. chemical storage assessments, chemical movement assessments, chemical usage risk assessments.
- Individual procedural analysis: e.g. single process risk assessments, work position manufacturing operation risk assessment, manual/automatic machine operations risk assessments, maintenance risk assessments.
- Visual management in manufacturing e.g. caution signs, exit and entry signs, moving vehicle signs, walkways, protective equipment signage, chemical signs, mandatory action signs, prohibition signs.
- Manufacturing guidelines for correct equipment use.
- Safety managers, line inspections and safe working practice monitoring.
- Production line safety systems, e.g. infrared monitoring, movement sensors, torque trips.

D2 Battery handling safety protocols

- Potential hazards related to battery handling:
  - electrical, e.g. shocks, insulation testing procedures, electro-static build up
  - heat, e.g. burns, cooling failures, component damage, welding arcs
  - chemical, e.g. coat materials, powder coating, respiratory challenges.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know about batteries used in electric and hybrid vehicles		
A.P1 Identify battery types used in electric and hybrid vehicles. A.P2 Describe different interactions between batteries and vehicle power systems in electric and hybrid vehicles.	A.M1 Explain interactions between different battery types and electric and hybrid vehicle power systems.	AB.D1 Evaluate different types of battery used in electric and hybrid vehicles in terms of operating principles, vehicle interactions, energy efficiency and suitability of application.
Learning aim B: Understand the operating principles of electric and hybrid vehicle batteries		
B.P3 Explain the operation of two typical types of electric/hybrid battery.	B.M2 Analyse in detail the operation of two typical types of electric/hybrid battery within different vehicles.	
Learning aim C: Explore electric and hybrid vehicle battery manufacturing		
C.P4 Describe the battery cell construction process for a commonly used type of electric/hybrid battery. C.P5 Describe the battery module construction process for a commonly used type of electric/hybrid battery. C.P6 Describe the battery pack construction process for a commonly used type of electric/hybrid battery.	C.M3 Explain the manufacturing process of a common battery cell, module and pack used in electric and hybrid vehicles.	C.D2 Assess the efficiency of processes and testing during the manufacture of electric and hybrid battery modules.

Cont.

Pass	Merit	Distinction
Learning aim D: Know about safe working practices when manufacturing electric and hybrid batteries		D.D3 Compare safety protocols in general manufacturing, and a battery manufacturing, environments and the potential safety measures that could reduce the risks.
D.P7 Describe key safety protocols used in manufacturing environments. D.P8 Describe the use of additional safety protocols needed in battery handling environments.	D.M4 Explain key safety protocols in a general, and battery-specific, manufacturing environment.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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.P6, C.M3, C.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 a range of information sources related to battery types, operational information and construction processes. It would benefit learners if the manufacturers and battery types were those that they have access to and are more likely to gain experience working with. Learners would also benefit from details of the manufacturing layouts and processes at each stage and how the components are tested before and after full assembly.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will need to demonstrate they have researched and understood the various hybrid and electric vehicle batteries that are available for common use. They must evaluate the operation of two types of electric and hybrid vehicle battery and the levels of interaction they have with other vehicle systems. Learners must also include in their evaluation evidence of the use of data to allow judgements to be made about efficiency, output levels and lifespan of the two types of battery.

For Merit standard, learners need to explain the interactions and links between electric vehicle and hybrid vehicle battery types and wider vehicle power systems, for example start/charge systems, electric steering, electronic brake systems. Learners must then analyse how two different battery types operate under different scenarios to produce drive and ancillary functions, for example stop-start traffic or constant speed cruising on highways.

For Pass standard, learners must show that that they can identify examples of a range of battery types that are used in electric and hybrid vehicles, based on information such as their chemical components or through manufacturers' descriptions. Learners also need to describe the common interactions between vehicle systems and the main power battery. This must include details of one interaction with hybrid vehicles and two interactions within electric vehicles. Learners need to also include information about the changes needed in some traditionally mechanical and/or fluid-based systems that cannot function correctly within electric vehicle systems. Learner should then select two of the available battery types and explain their construction and operating processes in terms of their working cycles.

Learning aim C

For Distinction standard, learners need to assess a full battery manufacturing process, reviewing the construction processes that make up each stage of the cell, module and pack build. Learners will need to assess each main process stage, including the machinery and equipment needed to complete each construction stage and why they are used. Learners should highlight the human interactive stages, the semi-automatic stages and the fully automated stages. Learners should comment on the suitability of these processes and their efficiency during the manufacture and testing of the electric and hybrid battery modules.

For Merit standard, learners need to review a suitable manufacturing process for a full battery end to end process. The learner must cover the three levels of production: cell, module and battery pack. The learner should explain what happens at each point of the

process and how this is completed. The explanation should include details of operator and automated processes.

For Pass standard, learners need to describe the manufacturing process and equipment needed to produce a battery cell for an electric or hybrid vehicle. All main construction steps should be described including the equipment and machinery used in the process. Learners should review the module construction process and the pack construction process in a similar manner. Learners should describe the automatically and manually completed operations and how the products are tested at each stage.

Learning aim D

For Distinction standard, learners must review safety protocols used in manufacturing and in the battery handling and manufacturing process. Learners should then compare the protocols in both production environments and identify the similarities and the differences. The learner should clearly identify any safety measures that specifically reduce risks in the battery manufacturing environment and justify why these measures are needed.

For Merit standard, learners must explain the key safety protocols used in general manufacturing environments and also in battery handling and manufacturing environment. Learners should clearly explain the reason for the protocol in these environments and the impact on the process and operators if these protocols fail.

For Pass standard, learners need to describe the key safety protocols used in manufacturing settings. Learners should include details of why they are in place and who they affect, making references to appropriate regulations. Learner should use their understanding of manufacturing protocols to describe the additional safety measures that need to be in place for battery handling and manufacturing environments.

Links to other units

This unit links to:

- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 62: E–mobility
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems.

Employer involvement

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

- technical specialist to discuss technology changes associated with electric and hybrid vehicles
- work experience
- brochures and technical material as exemplars
- visits to appropriate automotive organisations that manufacture electric or hybrid vehicles.

Opportunities to develop transferable employability skills

- Identifying questions to answer when investigating electric and hybrid vehicle batteries and associated systems.
- Organising time and resources and anticipating and managing risks when researching electric and hybrid vehicle battery technologies.

Unit 60: Electric and Hybrid Vehicle Motors

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers the main types of motor that are used in electric and hybrid vehicle drive systems. Learners will develop an understanding of the use of different varieties of AC and DC drive motors, and the positioning of single and in-wheel motor drive systems in relation to the vehicle and the advantages and disadvantages these placements provide. The structure of the in-wheel motors and their operating process will be evaluated. The single motor drive system will be explained together with the additional component requirements to support this drive type. The internal structure of the motor and the different wiring and operating systems will be examined. This will include the variety of rotor types and the manufacturing process differences needed to create these varieties. The stator wiring systems will be explored, and the operation of the various types explained. The manufacturing process for the variety of rotors and stators will be explained and evaluated for efficiency of design, ergonomically measured using lean manufacturing tools. Safety issues will be reviewed and evaluated. The common and specialist manufacturing equipment used in the construction process will be identified and explained. A case study could be used to show a typical construction line for rotors, stators and complete motor units.

Learning aims

In this unit you will:

A Know about the design and functioning processes of hybrid and electric vehicle motor drive systems

B Know about electric vehicle motor types, construction and operation

C Know about electric vehicle motor manufacturing equipment and processes

D Understand safety and manufacturing ergonomics relevant to electric vehicle motor manufacturing.

Unit content

Learning aim A: Know about the design and functioning processes of hybrid and electric vehicle motor drive systems

A1 Power and drive systems used in hybrid vehicles

- Drive system:
  - in gearbox motors:
    - location: in gearbox powerline, link to output shaft, electrically variable transmission assembly
  - flywheel motors:
    - location: between engine and gearbox, within flywheel.
- Operating layout:
  - in gearbox motors:
    - construction: rotor, stator, cooling components, inverter, mechanical gearbox
  - Flywheel motors:
    - construction: rotor, stator, cooling components, flywheel components, housing, disconnection clutch, hydraulic system.
- Component function:
  - gearbox motor:
    - rotor function, stator function, housing systems, driveshafts, drive gears
  - flywheel motor:
    - rotor, stator, damper, one way clutch, disconnection clutch actuator, cooling channel.

A2 Power and drive systems used in electric vehicles

- Drive system:
  - direct drive: motors are located at each drive wheel, rotor, stator, wheel bearing, operating electronics, cooling system
  - indirect drive single motor systems: single motor fitment, locations, fixed ratio gearbox, driveshafts, differential and constant velocity joints.
- Operating layout:
  - direct drive:
    - rotor positioning, e.g. fixed to wheel, mounted on the wheel bearing
    - stator: mounted on backplate/suspension components, contains electronics
  - indirect drive single motor systems: rotor, centrally mounted, gear drive to drive output shaft;
    - Stator: mounted around the rotor in the gearbox casing, linked to electronic controls, inverter, epicyclic geartrain, diff drive, output shafts.
- Component function:
  - direct drive:
    - rotor, stator, electronics, cooling system, bearings
  - indirect drive:
    - rotor, centrally mounted, gearing systems, cooling systems, differential system.

Learning aim B: Know about electric vehicle motor types, construction and operation

B1 Commonly used electric vehicle motor types and their operation

- AC motors:
  - asynchronous motor: squirrel cage type, wound rotor type; slip between speed and magnetic field
  - synchronous motor: synchronous induction, permanent magnet, rotor and magnetic field speed
  - rotor winding: hairpin or stranded wire
  - operating principles: asynchronous, synchronous.
- DC motors:
  - brushless: electronically commutated motor, permanent magnet rotor
  - brush type: series wound, separately excited shunt wound
  - operating principles.

B2 Stator construction types and operation

- Stator construction types.
- Star wound construction.
- Delta wound construction.

B3 Rotor construction types and operation

- Rotor construction types:
  - squirrel cage, permanent magnet, wound synchronous rotor, hairpin, stranded wire.

Learning aim C: Know about electric vehicle motor manufacturing equipment and processes

C1 Commonly used manufacturing equipment

- Common machinery, e.g. wire feeding and straightening tools, bending tools; laser welding tools, moulding machines, presses, lathes, demoulding and cleaning machines, heating and cooling machines, gasket machinery, drilling.
- Specialist tools, e.g. hairpin insertion tools, winding machines, stator lacing tools; resin application machinery; powder coating machines; potting machines, balancing machine.

C2 Electric motor manufacturing processes

- Rotor construction processes e.g. paper preparation, shaft press, slot insulation, star disc assembly, winding, paper and slot wedges insertion, cup assembly, connection and welding, electrical testing, impregnation, balancing, machining slip ring, electrical test.
- Stator construction processes e.g. slot insulation, winding, insertion, int. form, connection, lacing, final forming, testing, impregnation, testing.
- Unit construction processes e.g. housing heating rotor mounting, bearing and gear assembly and fitting, drive cover assembly, leak pressure testing, final assembly, electrical testing.

Learning aim D: Understand safety and manufacturing ergonomics relevant to electric vehicle motor manufacturing

D1 Safety in electric vehicle motor manufacture

- Potential threats related to motor production:
  - electrical, e.g. shocks, insulation testing procedures, electro-static build up
  - heat, e.g. burns, cooling failures, component damage, welding arcs
  - chemical, e.g. coat materials, powder coating, respiratory challenges.

D2 Ergonomic layouts and processes in electric vehicle manufacture

- Ergonomic design: e.g. lean manufacturing processing, workplace organisation, kaizen pods, access points, parts delivery systems, shortest distance travelled, process balancing.
- Machine placement, e.g. power supply, line position, material delivery, safety risks, heat and light generation, chemical management and use.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know about the design and functioning processes of hybrid and electric vehicle motor drive systems		A.D1 Evaluate the efficiency and use of two motor drive systems types for one hybrid and one electric vehicle applications.
A.P1 Describe one common motor drive system used in a hybrid vehicle application. A.P2 Describe one common drive system used in an electric vehicle application.	A.M1 Explain the design and functioning processes of two motor drive systems for one hybrid and one electric vehicle.	
Learning aim B: Know about electric vehicle motor types, construction and operation		B.D2 Evaluate construction and operation of AC and DC motors, rotor and stator types, in electric and hybrid vehicle applications.
B.P3 Describe commonly used motor types for AC and DC drive motors. B.P4 Describe the construction and operation of stator and rotor type motors used in electric vehicles.	B.M2 Explain the construction and operation of AC and DC motors, including stator and rotor types, used in electric vehicles.	
Learning aim C: Know about electric vehicle motor manufacturing equipment and processes		C.D3 Analyse the manufacturing process and equipment used to construct an electric or hybrid vehicle motor system.
C.P5 Describe commonly used and specialist manufacturing equipment used to construct electric or hybrid vehicle motors. C.P6 Describe one electric or hybrid motor manufacturing process.	C.M3 Explain one electric or hybrid vehicle motor manufacturing process including the commonly used and specialist equipment used in its construction.	

Cont.

Pass	Merit	Distinction
Learning aim D: Understand safety and manufacturing ergonomics relevant to electric vehicle motor manufacturing		
D.P7 Explain safety issues that can occur within vehicle motor manufacturing for use in electric drive systems. D.P8 Describe ergonomic factors that need to be considered when manufacturing electric and hybrid vehicle motors.	D.M4 Analyse safety and ergonomic factors which must be considered when creating a manufacturing process for electric and hybrid vehicle motors.	D.D4 Evaluate an electric vehicle drive system manufacturing process for its safety procedures and use of ergonomic production layouts.

Essential information for assignments

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

There is a maximum number of four 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)

Learning aim: C (C.P5, C.P6, C.M3, C.D3)

Learning aim: D (D.P7, D.P8, D.M4, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a variety of information and data sources specific to the use of electric motors in both electric and hybrid vehicles. They will need access to information about motor theory and the variety of motor types used in electric and hybrid vehicles. Access to manufacturing information, including automation, machinery, construction stage information and testing processes, will also be needed.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will need to locate information on a motor drive system for an electric and for a hybrid vehicle. Learners can choose the types of motor and their locations; however their evaluations must include details of the efficiency of their chosen motor drive system and include comparisons with alternatives, including alternative motor locations.

For Merit standard, learners need to explain the design and construction of two motor drive systems. They must include one electric vehicle and one hybrid vehicle motor drive system. The explanation can be either single or at wheel motors for an electric vehicle. For a hybrid vehicle motor this could either increase the torque or fully power the vehicle. Learners will need to explain the working processes of each of the motors and associated components and how they provide drive for the two vehicle types.

For Pass standard, learners must describe a commonly used motor drive system for one electric vehicle and one hybrid vehicle. For the electric vehicle this can be from either a single motor system or a multi-motor type. Learners will need to describe the location and operation of each motor, including the components they are attached to. Learners will need to also describe a hybrid vehicle motor drive system. Learners can describe a motor that delivers additional driving torque or one that drives the vehicle independently. The description should include the position and operation of each drive system component, its location and how it links to any mechanical systems.

Learning aim B

For Distinction standard, learners will evaluate the construction and efficiency data available for the four different types of motor that have been researched for both electric and hybrid vehicles. Learners should make comparisons between the operation of each type and torque delivery at all speed ranges, giving advantages and disadvantages of the different motors when used in electric and hybrid vehicles.

For Merit standard, learners need to explain the construction of AC and DC motors used in both electric and hybrid motors. They will need to include details of AC synchronous and asynchronous motors including their rotor and stator wiring methods and DC brushless and brushed motors. They need to included details of the components of the motors, explaining their purpose and how they work with other components to make the motor function correctly. Learners need to explain the operating applications of each of these four types of motor and why they have been used in that situation.

For Pass standard, learners need to describe at least one example of each type of motor included in the unit content that are used commonly on both electric and hybrid vehicles. For AC motors they need to include descriptions of synchronous and asynchronous motors and their rotor and stator wiring methods. For DC motors they must include both brushless and brushed motors, again with details of rotor and stator wiring methods. Learners need to describe the operation of a synchronous and asynchronous AC motor and a brushless and brushed DC motor, including their internal wiring systems. Learners should include details of magnetic impacts, permanent magnets rotors, slip between the magnetic field and rotor speed and how these affect motor performances.

Learning aim C

For Distinction standard, learners must choose a type of AC or DC motor that is used in electric or hybrid vehicles. Learners should analyse the manufacturing process that is used to construct the motor system from rotor and stator construction to final assembly within the drive placement. Learners should analyse the use of commonly used equipment and automation within the manufacturing process including any specialist equipment. Learners should give reasons why these processes and equipment are used instead of alternatives.

For Merit standard, learners need to explain either a hybrid or electric vehicle motor manufacturing process. This could be for any of the motor types used in these vehicle types. Learners need to explain each stage of the process including the equipment used in the line construction process. Learners need to cover at least three examples of commonly used equipment, three examples of specialist equipment and any special processes that are needed for the construction process.

For Pass standard, learners must investigate and describe commonly used manufacturing equipment that is used to construct electric or hybrid vehicles. The common types should include at least three of the following: drills, lathes, moulding machines and presses. Learners must also consider at least three examples of specialist machinery, for example winding and insertion machines, resin machines, powder coating machines and rotor balancing machines. Learners then need to select either an electric or hybrid motor manufacturing process and describe each of the manufacturing phases used during the construction of the motor, including details of the equipment used.

Learning aim D

For Distinction standard, learners will show an understanding of manufacturing processes and the tools that support the evaluation of ergonomic production layouts. These could include lean principles, workplace organisation and station balance times. Learners should evaluate the whole of the manufacturing process in terms of ergonomic design and safety systems that are in place on the manufacturing line.

For Merit standard, learners will have reviewed a typical electric or hybrid vehicle motor manufacturing environment. They will use this knowledge to explain why safety protocols and ergonomic factors must be considered when creating a new manufacturing line for electric and hybrid vehicle motors. Learners must include details of specific safety protocols that will be required, including those for hazards associated with heat, electricity and chemicals, and the reasons why ergonomics play such an essential role within line design for electric or hybrid vehicle motor manufacturing.

For Pass standard, learners need to use safety data and investigations to identify and describe at least eight common safety issues that can occur within a vehicle motor manufacturing setting. This should cover safety issues created by the machines used, the chemicals used in the process, and sound and sight dangers such as loud repetitive noise or lights from welding processes. At least one example of safety issues related to heat, electrical and chemicals must be included. Learners need to describe common ergonomic factors that can impact online production and state how and why it is important to take these factors into account when designing a manufacturing system for electric or hybrid vehicle motors.

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 61: Electric Vehicle Drives
- Unit 62: E–mobility
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems.

Employer involvement

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

- technical specialist to discuss electric and hybrid motor impact and technology
- work experience with electric and hybrid vehicles
- electric or hybrid vehicle motors as exemplars
- visits to appropriate automotive or manufacturing organisations where motors for EV and hybrid vehicles are manufactured.

Opportunities to develop transferable employability skills

- Research, presentation and formal written communication skills.
- Analysis skills when reflecting on a given issue.
- Independent working practices when completing an assignment or task.

Unit 61: Electric Vehicle Drives

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers the electric and hybrid vehicle transmission system. This will include the location of the drive motors in electric vehicles, single motor and multi-motor layouts, the advantages and disadvantages of each and their operating efficiency. The different varieties of hybrid vehicle layouts will be studied, including the various motor assistance layouts and the most popular placements for the motor/mechanical combinations reviewed. Learners will also investigate the three main combination types, parallel, series and power split systems, their sub systems and the variations of each. Learners will explore the operation of the motors and transmission systems to provide electrical assistance at all levels from simple stop-start systems to fully electrical drive systems.

Learners will investigate the manufacturing process and systems that are needed to create electric and hybrid transmission systems. A full production line process will be studied and assessed. Learners will review the product creation stages and the equipment needed to complete these stages. The review will include an overview of each machine type, factory layout and lean manufacturing principles assessment. The complex nature of the construction process can raise safety concerns. This unit will review general and specific safe working practices, personal protection, the impact of electrostatic discharge can have during the manufacturing process and how to protect from this.

Learning aims

In this unit you will:

A Know about the operating principles of electric vehicle drive systems

B Know about the operating principles of hybrid vehicle transmission systems

C Understand electric and hybrid vehicle transmission manufacture and assembly

D Understand safe working practices when manufacturing electric and hybrid vehicle transmission systems.

Unit content

Learning aim A: Know about the operating principles of electric vehicle drive systems

A1 Single motor drive systems used in electric vehicles

- Principles of single motor drive systems:
  - potential motor positions in the vehicle structure
  - manufacturer motor positioning variances
  - motor torque outputs e.g. torque delivery in the speed range, torque multiplication needs
  - single motor drive operation
  - advantages and disadvantages of single motor electric vehicles e.g. cost of manufacture, reduced vehicle costs, reduced weight, requires gearing, driveshafts and differentials, good sprung weight characteristics, less battery space options, weight distribution, regenerative braking.

A2 Multiple drive motor layouts, at or in wheel

- Principles of multiple drive motor drive systems:
  - potential motor positions in the vehicle structure
  - manufacturer motor positioning variances
  - motor torque outputs e.g. torque delivery in the speed range, torque multiplication needs
  - advantages and disadvantages of multiple motor electric vehicles e.g. precise torque delivery, multi-torque level delivery, speed variances at each wheel, reduced component needs, increase available location space for the battery, unsprung weight increase, needs enhanced suspension design to improve ride quality, more complex motor cooling systems.

Learning aim B: Know about the operating principles of hybrid vehicle transmission systems

B1 Hybrid vehicle drive system layouts

- Hybrid impact levels and the set ups they employ:
  - stop/start: fuel reduction etc
  - mild hybrid
  - strong hybrid
- Common types of hybrid vehicle layout; parallel, series and power split systems.
- Hybrid electric motor standardised categories:
  - P classifications for motor placements:
    - P0 engine front end accessory drive (FAED) locations
    - P1 engine rear locations directly to the crankshaft
    - P2 between the engine and the transmission
    - P3 within the transmission or post- transmission prior to the differential
    - P4 within the axle drive system
    - PS power split device, planetary gearset
  - EE axle drive system.
- Sub system types, layouts and components:
  - parallel hybrid single clutch systems
  - parallel hybrid two clutch system
  - parallel hybrid double clutch transmission

- axle split parallel hybrid
- series hybrid
- series parallel hybrid
- power-split hybrid.

B2 Hybrid vehicle transmission systems construction and operation

- Hybrid transmission systems:
  - adapted flywheel drive systems
  - transmission motor drive systems
  - axle motor drive systems
  - different drive systems efficiency and torque production.
- Hybrid transmission unit construction:
  - adapted flywheel drive systems
  - transmission motor drive systems
  - axle motor drive systems.
- Hybrid transmission unit operating principles:
  - adapted flywheel drive systems
  - transmission motor drive systems
  - axle motor drive systems.

Learning aim C: Understand electric and hybrid vehicle transmission manufacture and assembly

C1 Transmission unit production processes

- Stages of transmission construction (insertion, load, press, tightening, measuring, marking, apply sealants, rollover, leak test, in process verification).
- EV component production e.g. rotor, stator and inverter.
- EV component construction process e.g. housing construction, stator inserting, bearing pressing, rotor insertion, final assembly, testing.
- Line construction: construction flow, efficient line design, lean impacts, robot placement, transportation systems, automated stages, manual task stages, testing zones, reworking areas.

C2 Transmission unit construction equipment

- Line machinery e.g. robotic stations, automated single operation machinery, automated multistage machinery, semiautomated machines, manually-operated machinery.
- Hand tools e.g. air operated assembly tools, spanners, specialist sockets, spline tools.
- Measuring tools e.g. pressure testers, torque testers, power testers, electronics testers.

Learning aim D: Understand safe working practices when manufacturing electric and hybrid vehicle transmission systems

D1 Hazard identification in the manufacturing process

- Risk assessment of manufacturing processes: common dangers, specialist assessments, chemical evaluations, individual process analysis.
- Common hazard signage in manufacturing e.g. caution signs, exit and entry signs, moving vehicle signs, walkways, protective equipment signage, chemical signs, mandatory action signs, prohibition signs.

D2 Personal protective equipment requirements

- Basic personal protection in manufacturing:
  - workwear e.g. risk assessed requirements, safety footwear, protective clothing
  - specialist personal protective equipment e.g., eye protection, gloves, ear protection, hard hats, breathing equipment, face coverings.
- Anti-static protection:
  - impacts of static in electronic production process e.g. product failure, system failure, production reworking, estimated costs of electrostatic discharge damage in manufacturing
  - potential damage caused by static in production situations e.g. circuit damage, component damage, explosions, fires, robotics damage
  - equipment used to prevent static damage e.g. anti-static benches/line positions, antistatic accessories, antistatic lights, anti-static chairs, anti-static mats, plastic.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know about the operating principles of electric vehicle drive systems		
A.P1 Describe the location and operation of a single motor in a front or rear wheel drive electric vehicle. A.P2 Describe the location and operation of a multi-motor drive system used in an electric vehicle.	A.M1 Explain the similarities and differences in the location and operation of single and multi-motor drive systems.	AB.D1 Evaluate electric and hybrid vehicle drive and transmission systems in terms of their efficiencies, motor locations and the need for transmission systems or direct drive.
Learning aim B: Know about the operating principles of hybrid vehicle transmission systems		
B.P3 Identify a range of hybrid vehicle drive system layouts. B.P4 Describe the operation of three hybrid vehicle electric motor systems.	B.M2 Compare the electric motor assistance given, and the way each system provides drive, for two hybrid vehicle systems.	
Learning aim C: Understand electric and hybrid vehicle transmission manufacture and assembly		
C.P5 Describe an electric/hybrid vehicle transmission manufacturing and assembly process. C.P6 Explain equipment needed to manufacture and assembly of electric/hybrid vehicle transmissions.	C.M3 Assess the manufacturing and assembly process for an electric/hybrid vehicle transmission in terms of the operations carried out and the equipment used.	C.D2 Evaluate the manufacture and assembly process for electric/ hybrid vehicle transmissions, in terms of processing, efficiency in operation and potential improvements.

Cont.

Pass	Merit	Distinction
Learning aim D: Understand safe working practices when manufacturing electric and hybrid vehicle transmission systems		
D.P7 Explain common and specific safe working practices required in an electric/hybrid drive system manufacturing and assembly process. D.P8 Describe the correct personal protective equipment required when manufacturing and assembling electric/hybrid vehicle drive systems.	D.M4 Assess the effectiveness of safety systems, protective equipment and risk management process relevant to an electric/hybrid vehicle drive system production process.	D.D3 Evaluate the effectiveness of safety practices and protocols used in an electric/hybrid drive system production and make recommendations for improvements.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a range of transmission types (clutches, gearboxes and driveline/final drives) and their components. A variety of information and data sources specific to the transmission systems will also be required. Learners will need access to the special tools and equipment needed for investigation and routine maintenance of the selected transmission systems as defined in the unit content and assessment criteria.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will need to produce an evaluation of electric and hybrid vehicle drive and transmission systems that demonstrates an in-depth understanding of light vehicle electric and hybrid vehicle layouts, motor position options and the advantages and disadvantages of each. Learners will need to evaluate the associated drive systems for suitability and efficiency and the assistance they can offer to hybrid mechanical systems. Learners will need to evaluate advantages and disadvantages of transmission drive systems to the direct drive system. The evaluation should include consideration of weight, unsprung mass, torque delivery, vehicle control and regeneration of energy.

For Merit standard, learners need to demonstrate their understanding of the range of electric motor layouts used in current electric vehicles. They must explain the operations of the single and multi-motor systems, including details of their efficiencies and potential detractions. Learners will need to explain the similarities and differences of single and multi-motor dive systems by comparing the two systems. Learners will investigate the hybrid systems available, comparing motor locations, working processes and the amount of assistance the electrical systems give to the mechanical processes. Learners should review the effect the intervention has and how these interventions are suited to the driving situations.

For Pass standard, learners must show that they can clearly describe the layout of single motor electric vehicles, this can be front or rear mounted motors. Learners will describe how the systems operate and how they link to the mechanical systems of the vehicle. Learners will also describe the layout of multi-motor vehicles and how they compare to the single motor systems. Learners should describe the unique advantages of both single and multi-motor vehicles and their use . Learners must describe the operation of multi-motor electric vehicles and why motors are located at the wheels.

Learners will review a range of hybrid vehicle types and identify their purpose and classification in terms of motor layout, sub system types, layouts and components. Learners need to differentiate between levels of intervention and their associated efficiency gains. Once a range of systems has been identified the learner will need to describe their operation of at least three hybrid vehicle electric motor systems. The description must include details of how the systems provide electrical assistance and the level of assistance that the system can provide.

Learning aim C

For Distinction standard, learners must produce an evaluation that includes a review of the manufacturing and assembly process for an electric or hybrid vehicle transmission. They will consider the assembly line and evaluate the stages of manufacture of the transmission system in terms of the operations being completed. Learners will consider the interaction between human and automated actions in the processes and evaluate the efficiency of these processes before identifying potential improvements to the assembly process.

For Merit standard, learners will assess the manufacturing process for an electric or hybrid vehicle transmission system. The learner will assess the processes used during the construction of the transmission system, the equipment used during the process and movement of the components between stations. Learners will include details of the function of each machine used and also consider the efficiency of the manufacturing process overall.

For Pass standard, learners need to describe one manufacturing process that is used for the construction of an electric or hybrid transmission system. Learners will describe each stage and the processes used. They will also describe the equipment and machinery used at each station and the processes completed by each of the machines. Learners will describe the functions of each of the pieces of equipment and the efficiency of each in its role. Learners should also describe the differences between robotic equipment, automated machinery and manually operated machines.

Learning aim D

For Distinction standard, learners will evaluate the effectiveness of safety practices and protocols. They should demonstrate research of safety practices that are used in a electric/hybrid drive system manufacturing environment. Learners will evaluate the standard and specific safety requirements that would be present in the electric/hybrid production environment, considering the effectiveness of these requirements in reducing incidents and accidents. Learners will need to include particular issues that can occur in electrical/electronic environments as part of their evaluation. Learners will evaluate all the safety systems and protocols that are in place and make recommendations for improvements that might be necessary.

For Merit standard, learners will assess the need for safety assessments and the processes used to identify and manage the risks that are related to the manufacturing environment for electric and hybrid drive systems. Learners will assess the effectiveness of personal protective equipment as a method for preventing potential harm from the risks identified. Learners should consider a range of risks including general risks and those risks specific to electrical and mechanical equipment construction and manufacturing processes.

For Pass standard, learners must explain the common safety risks that are present when manufacturing and assembling electric/hybrid drive systems. This should include safety management processes and signage use to maintain a safe working environment. Learners should explain key safe working practices, for example with respect to anti-static measures, that are relevant to the production of electric and hybrid vehicle transmission systems. Learners need to explain how risk assessment processes need to be applied to each manufacturing stage. Learners will describe the correct personal protective equipment that is required in a manufacturing setting, including details of its specific use, protections and how to care for equipment.

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 62: E–mobility
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems.

Employer involvement

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

- technical specialist to discuss manufacturing of electric and hybrid transmission systems
- work experience with electric or hybrid vehicles
- technical material as exemplars
- visits to appropriate organisations where drive systems for electric and hybrid vehicles are manufactured.

Opportunities to develop transferable employability skills

- Research, presentation and formal written communication skills.
- Analysis skills when reflecting on a given issue.
- Analysis skills when assessing risks associated with manufacturing activities.
- Independent working practices when completing an assignment or task.

Unit 62: E–mobility

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers the factors that provide the infrastructure and laws and policies required to allow electric vehicles to grow in popularity, meet the targets set out in international collaborations and to deal with the potential environmental impacts that electric vehicles may have. Starting with the infrastructure requirements, learners will look at the requirements for charging networks to allow electric vehicles to work continuously as transport vehicles and to be recharged in a timely and convenient manner. This will include road network charging systems and home charging requirements. Learners will research and review the various pieces of legislation that control the production and construction requirements of electric vehicles including environmental impact, safety features, component location and driving safety systems. Learners will review the lifecycle of electric vehicles, the impacts of the construction phase on the environment and the location of construction materials. They will also examine the use phase of electric vehicles and the potential life span of components. Learners will learn about the potential end of life processes that can improve battery life and reuse rather than destruction. Learners will look at material salvage if reuse or recycling are not an option. The final part of this unit looks at the developments within fuel cell technology and its applicability as a power source for electric vehicles. Learners will look at the potential positives and current negatives of fuel cells and the distance they need to travel to be more effective as fuel sources in vehicles.

Learning aims

In this unit you will:

A Know infrastructure necessary to support full electric and hybrid vehicle integration

B Know policies that manage the transition to environmentally supportive transport

C Understand end of life requirements of electric and hybrid vehicles

D Understand other efficient fuel systems available for vehicles.

Unit content

Learning aim A: Know infrastructure necessary to support full electric and hybrid vehicle integration

A1 Charging systems and locations to meet customer needs

- Battery charging methods (current and proposed):
  - AC charging systems: industry acceptance, implementation and usage costs, potential installation sites and customer usage.
  - DC charging methods (low and high): industry acceptance, implementation and usage costs, potential installation sites and customer usage
  - inductive charging: likelihood of acceptance, working process, potential costs, potential positives and negatives
  - battery replacement: likelihood of adoption of the method, need for standardisation, potential journey pause time, storage and the requirements of a change station.
- Charging modes for safe charging and to suit manufacturers' chosen charging plug options, charging power source, maximum charging power, interactive communication processes:
  - mode 1 max power level: electrical input requirement, communication availability and impact, connection types, safety systems
  - mode 2 max power level: electrical input requirement, communication availability and impact, connection types, safety systems
  - mode 3 max power level: electrical input requirement, communication availability and impact, connection types, safety systems
  - mode 4 max power level: electrical input requirement, communication availability and impact, connection types, safety systems.
- Charging system plug variety and application e.g. type 1 single phase system, type 2 power supply and charging system variation, vehicle receiver variations.
- Wireless power transfer types (stationary, quasi-dynamic and dynamic), power levels (light duty, light duty fast charge and high/heavy duty), benefits, potential development for the future.

A2 Specific vehicle repair networks

- EV repair networks: what do we need them for, will slow growth impede EV take up, staff requirements, additional specialist equipment.
- Safety systems of work when completing repairs on EV and hybrid HV systems.
- Repair staff training/updating requirements (qualifications, typical training scenarios, typical hazards during repairs).
- How existing roadside support and repair systems can adapt to electric and hybrid vehicles (emergency starting, roadside repair methods, recovery and towing, emergency and fire procedures).

Learning aim B: Know policies that manage the transition to environmentally supportive transport

B1 Environmental regulations affecting electric and hybrid vehicle development

- End of Life Vehicle (ELV) Directive 2000/53/EC and the equivalent regulations outside of the EU, vehicles covered, cars and light vans, recycling targets; 95% of vehicles to be reused, recycled or recovered; authorised recycling centres operations e.g. vehicle stripping, de-polluting environmentally hazardous components.
- Global agreements (CO_2 reduction targets, differences between developed countries and the least developed countries legal targets, 2030 deadlines for change, 2050 targets) e.g. the Paris Agreement.
- Worldwide harmonised light vehicles test procedure; a global standard for vehicle data measurement (pollutant levels, $C0_2$ emissions, fuel or energy consumption and electric range).
- Local and regional regulations that can affect electric and hybrid vehicles.

B2 Vehicle-based laws and policies that effect electric and hybrid vehicle development

- ECE-R100 regulations for the harmonisation of EV systems on vehicle category M and N.
- Requirements from law and policies:
  - safety systems: shock protection e.g. HV systems in the compartments for passengers and luggage can't be touched, any HV system protection carries a danger symbol, traction battery and powertrain must correctly fused or contain circuit breakers, HV powertrain must be isolated from other EV systems
  - charging processes e.g. electric vehicles should not be able to move when charging, protection for charging equipment under any circumstance, plug systems should disable vehicle operation
  - general safety and driving requirements e.g. vehicle starting must be controlled, key removal stops driving ability, notification of movement readiness, early warning of battery discharge, driving mode warning systems, direction changes are managed through switching or double actuations, driver warning systems when vehicle issues occur.

Learning aim C: Understand end of life requirements of electric and hybrid vehicles

C1 Vehicle life cycle

- Three stages of the vehicle life cycle: production, use and recycling.
- Whole life cycle assessment, measuring $C0_2$ of a vehicle through production, use and recycling, typical vehicle comparison data comparing petrol, diesel and electric vehicles.
- $C0_2$ generation at each stage of vehicle production e.g. production data for each vehicle type, use data for each vehicle type and recycling data for each vehicle type.

C2 Battery end of life options and environmental impact

- Expected battery life span e.g. manufacture for vehicle life, minimum capacity levels e.g. 80%, 8 – 10 years:
  - battery construction materials (low impact, non- hazardous materials (lithium, sodium, copper, aluminum, plastic), high impact, heavy metals (cadmium) and toxic materials (nickel).
- Waste Batteries and Accumulators Regulations 2009: returning batteries to manufacturers, completing the 5R process.
- 5R solution and retained value:
  - recovery of battery from customers
  - repair the battery
  - remanufacture of the battery to return working capacity
  - reuse of batteries for non-automotive applications (household power storage, solar power systems)
  - recycle the battery by reclaiming usable materials.

Learning aim D: Understand other efficient fuel systems available for vehicles

D1 Use of fuel cells and super capacitors

- Fuel cells: common types (hydrogen, methanol), operating principles of hydrogen fuel cells, infrastructure requirements, potential gains and drawbacks of the hydrogen and methanol systems.
- Super capacitors: types (super, ultra), application within automotive circuits, links to energy recovery systems.
- Benefits of fuel cells and supercapacitors for reducing environmental impacts.

D2 Energy recovery systems

- Regenerative braking: theory of operation, difference in operation when fitted to conventional braking and EV braking systems, motor reversal process and driving impact.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know infrastructure necessary to support full electric and hybrid vehicle integration		
A.P1 Outline the suitability of different charging systems available for electric and hybrid vehicles in home, work and service station scenarios. A.P2 Describe requirements of a repair network sufficient to support electric and hybrid vehicles.	A.M1 Compare traditional fossil fuel infrastructures with electric and hybrid vehicle infrastructure.	A.D1 Analyse improvements needed to existing automotive infrastructure to support the growth of electric and hybrid vehicle use.
Learning aim B: Know policies that manage the transition to environmentally supportive transport		
B.P3 Describe given environmental policies that affect the production and use of electric and hybrid vehicles. B.P4 Describe ways that vehicle-based laws that can impact on electric and hybrid vehicles.	B.M2 Explain the impact of given environmental and vehicle-based laws/policies on the production and use of electric and hybrid vehicles.	B.D2 Evaluate the impact of given environmental and vehicle-based laws/policies have on the development and use of electric and hybrid vehicles.
Learning aim C: Understand end of life requirements of electric and hybrid vehicles		
C.P5 Describe the lifecycle for electric and hybrid vehicles. C.P6 Explain the end-of-life process for a range of battery types used in electric and hybrid vehicles.	C.M3 Assess the lifecycle and end of life processes needed to support electric and hybrid vehicles.	C.D3 Evaluate the lifecycle planning for electric and hybrid vehicles, vehicle recycling and battery reclamation processes.

Cont..

Pass	Merit	Distinction
Learning aim D: Understand other efficient fuel systems available for vehicles		D.D4 Evaluate the use of energy recovery systems on current electric and hybrid vehicles, how that energy is stored and recommend improvements.
D.P7 Explain the use of fuel cells, supercapacitors and energy recovery systems in vehicle fuel efficiency.	D.M4 Analyse the operation of energy storage and recovery systems used on current electric and hybrid vehicles.	

Essential information for assignments

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

There is a maximum number of four 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)

Learning aim: C (C.P5, C.P6, C.M3, C.D3)

Learning aim: D (D.P7, D.M4, D.D4)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a variety of information and data sources specific to the infrastructure required for EVs to develop in popularity in the learners' national and regional area.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will need to demonstrate their in-depth understanding of the required infrastructures needed for the growth of EV within communities and nations. Learners will need to clearly research each infrastructure need for EVs and then discuss the improvements that will be needed in each infrastructure area, for example with respect to the provision for public EV charging points, that in turn will support the growth of usage of electric and hybrid vehicles.

For Merit standard, learners need to demonstrate their understanding of fossil fuel vehicle infrastructure and the infrastructure needed for EVs. Learners need to investigate the different charging systems that will be required for EVs and compare these needs to the current fossil fuel provision. Learners will need to include information about the potential network changes that will be required for service stations to provide EV charging facilities and vehicle support. Learners need to consider the need for different systems to suit the charging demands of different manufacture's EVs when charging vehicles at home, at a place of work and also at service stations.

For Pass standard, learners must show that they have identified the different aspects of EV charging systems and explained their suitability for charging different vehicles at home, at an office or workplace and in a service station situation. The explanation should cover the different demands place by EV owners and their individual vehicles in each of the situations, such as the need for faster charging in a service station compared to at home. Learners will provide an explanation of the different charging modes used in EV charging, the safety levels for each mode and why they are used. Learners should consider charging times and the use of single and three phase power sources. Learners will include information about the three levels of wireless charging, the benefits of wireless charging and potential developments of this technology for the future. Learners will provide information on the current infrastructure available for EV support in their own region or country. Learners will need to describe each area of the network requirements. This will include describing the safety systems needed within a repair centre, staff training needs and any additional equipment that may be required. Learners should also provide details of the training needed for active repair staff and typical dangers that can occur in a repair environment. Learners will need to consider the roadside assistance currently available for fossil fuel vehicles and how this will need to change to suit a higher level of EVs on the roads.

Learning aim B

For Distinction standard, learners will need to evaluate a given environmental policy and a law that are linked to EV development and CO_2 management. Learners should fully evaluate the impacts these policies and laws have on the development and life cycle of electric and hybrid vehicles. Learners need to evaluate the impact of a policy and a law that dictates a range of development, construction and in use measures.

For Merit standard, learners need to review a given policy and a law and explain the main components of each and how they promote safety, conformity. The explanation will also need to provide details of the regulations that control environmental impact for vehicles for the future. Learners need to clearly explain the regulations that manage the design and production of electric and hybrid vehicles and how the vehicle lifecycle can impact on the environment.

For Pass standard, learners need to describe a given policy and a law that currently set out the goals for environmental impact reduction from vehicle pollutants and the impact of CO_2 throughout the vehicle life cycle. This should include a simple comparison between fossil fuel vehicle impact and the environmental impact of EVs through their lifecycle. The learner will then describe regulations that impact the build and use of electric and hybrid vehicles. Learners will need to describe any operational restrictions that are required for these types of vehicle to be used and what they achieve.

Learning aim C

For Distinction standard, learners must demonstrate research and evaluation of the current EV life cycle management processes that are currently set out. Learners should make sufficient judgements to determine the suitability of the recycling and reclamation processes that are currently used. They need to include details in their evaluation of the vehicle battery recycling requirements, including who is involved in the process and whether or not it is suitable to prevent further environmental impacts within the lifecycle of electric and hybrid vehicles.

For Merit standard, learners need to discuss the electric and hybrid vehicle life cycle including material sourcing, manufacturing, customer use, main component longevity and the processes and requirements of component reuse and recycling. Learners should give examples of potential battery remanufacturing options and provide information on the importance of remanufacturing as a method to reduce environmental impacts. They should review the potential options for recycling batteries, including the potential impact of each.

For Pass standard, learners need to review electric and hybrid vehicle life cycle examples, describing each stage and the resulting emissions of CO_2. Learners will investigate the processes required at each stage and how this combines to create a lower polluting vehicle. They will also need to describe a development that will continue to lower the environmental impact of road vehicles. Learners need to identify the highest polluting stages of the lifecycle and identify improvements that are planned for implementation. Learners will explain the end-of-life process for a range of battery types used in electric and hybrid vehicles, including their ability to be remanufactured, reused or recycled and the impact each of these can have on the environment. Learners should correctly rank these options from the most environmentally friendly to the least.

Learning aim D

For Distinction standard, learners need to research and evaluate the current energy recovery systems used on electric and hybrid vehicles. Learners should use that research to discuss and propose addition energy collection systems that could work or have been through proof-of-concept trials. Learners need to investigate the use, or potential use, of fuel cell technology and evaluate its potential use in electric and hybrid vehicles. Learners must clearly evaluate the positive and negatives of the use of fuel cells and any reasons that prevent their use in road going vehicles.

For Merit standard, learners need to analyse the use of fuel cells and super capacitors in vehicles to provide short- and long-term storage for recovered power. Learners should consider how the storage system operates in conjunction with available energy recovery systems. This can include current energy recovery systems that link to braking systems and power steering systems.

For Pass standard, learners need to review the current use for alternative fuel options that could be used for electric vehicles. Learners should describe the potential of fuel cell technology, including details of the benefits and restrictions that currently impact on their use in road vehicles. Learners should include information about the potential for environmental impact reductions with this technology and the issues such as heat and gas delivery systems. Learner should also describe the function and operation of a regenerative braking system that is used within electric vehicles and how this works to recharge the battery whilst slowing and stopping the vehicle.

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems.

Employer involvement

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

- technical specialist to discuss electric and hybrid impact and technology
- work experience with electric and hybrid vehicles
- technical material for electric and hybrid vehicles as exemplars
- visits to appropriate automotive organisations that provide support or infrastructure for electric and hybrid vehicles such as service centres.

Opportunities to develop transferable employability skills

- Reflecting when setting goals with success criteria for their development and work.
- Working in a team when collaborating with others to work towards common goals when researching petrol injection systems.
- Managing self when organising time and resources, prioritising actions.

Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

Electronic ignition systems have developed in line with the advancement of engine technology and engine management systems. Modern electronic ignition systems have improved vehicle reliability, performance and efficiency of vehicle operation. Recent advances in spark plug design, manufacture, operation and their longer working life have also improved the performance of electronic ignition systems.

It is important that all motor vehicle technicians are aware of these systems and are able to recognise and confirm faults. This unit will enable learners to understand the fundamental operating principles of electronic ignition systems and will give them the knowledge and understanding needed to carry out accurate fault diagnosis and repair. Learners will develop an understanding of the main components of vehicle electronic ignition systems and their relationship to the efficient operation of the engine unit and sub-systems.

Learning aims

In this unit you will:

A Understand the function and operation of conventional ignition systems

B Understand the operation of programmed electronic ignition and distributorless ignition systems

C Know about the function and operation of pulse generators and control modules

D Be able to undertake tests on electronic ignition system to verify system faults.

Unit content

Learning aim A: Understand the function and operation of conventional ignition systems

A1 Ignition system components

- Circuits:
  - circuit and wiring diagrams
  - primary circuit
  - secondary circuit.
- Ignition switch.
- Contact breaker.
- Induction coil: primary winding, secondary winding.
- Leads.
- Distributor and cap.
- Rotor arm.
- Spark plugs.
- Mechanisms:
  - mechanical (governor) advance
  - retard
  - vacuum advance.

A2 Ignition system operation

- Ignition timing:
  - static
  - dynamic.
- Dwell
  - angle
  - time
  - variation.
- Ignition scope patterns e.g. spark kV, primary circuit, secondary circuit, dwell, coil output.

Learning aim B: Understand the operation of programmed electronic ignition and distributorless ignition systems

B1 Programmed electronic ignition

- Components, functions and operation.
- Electronic control unit.
- Sensors e.g. manifold absolute pressure, crankshaft, camshaft, engine temperature, knock, air temperature, Hall-effect sensor.
- Ignition coil.
- Distributor.
- Ignition switch.
- Reluctor disc.
- Discharge e.g. capacitor, inductive.

B2 Distributorless ignition system

- Components, functions and operation.
- Control units: ignition control unit (ICU); engine control unit (ECU).
- Transformer.
- Capacitor.
- Ignition coil(s) e.g.:
  - waste spark
  - direct acting.
- Spark plug.
- Sensor e.g.:
  - manifold pressure
  - crankshaft position sensor
  - camshaft position sensor
  - knock.
- Primary current switching modules.
- Waste spark.
- Direct acting.

Learning aim C: Know about the function and operation of pulse generators and control modules

C1 Generators

- Hall effect e.g. Hall voltage, Hall integrated circuit (IC), vanes, magnet, control module.
- Inductive pick-up e.g. permanent magnet, inductive, windings, trigger wheel.
- Optical pulse e.g. light emitting diode, phototransistor.

C2 Transistor assisted contacts

- Transistor operation.
- Darlington pair.
- Advantages of breakerless systems.

C3 Control modules

- Operation e.g. pulse shaping, dwell period control, voltage stabilisation, primary switching, pulse processing, secondary output control, ignition amplifier, air gap, electronic spark advance, spark advance map, knock control/
- Program storage methods, e.g. read-only memory (ROM), erasable programmable read-only memory (EPROM).

Learning aim D: Be able to undertake tests on electronic ignition system to verify system faults

D1 Testing

- Equipment e.g. on-board diagnostics, test instruments, voltage drop tester, electronic control unit tester.
- Spark advance and retard tester.
- Safe working practice.
- Components and circuits, e.g. fuses, wiring, connectors, coil, spark plug, leads, rotor arm, distributor cap, pulse generator, sensors (such as crankshaft, camshaft, knock), break out box, ignition switch, reluctor air gap.
- Checking for faults, e.g. moisture, dirt, corrosion, fault code reading, gap, data link connection, output and resistance, spark plug leads condition and resistance, rotor arm condition and leakage, distributor cap condition and leakage, dwell angle, spark plug condition, pulse generator module resistance, ignition timing, sensor output, sensor operation.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the function and operation of conventional ignition systems		ABC.D1 Evaluate the operation of a conventional ignition system, a programmed electronic ignition system and a distributorless ignition system in a variety of cold start and acceleration situations.
A.P1 Describe the function of conventional ignition system components. A.P2 Describe the operation of a typical conventional ignition system.	A.M1 Explain the function and operation of components and operation of a typical conventional ignition system.	
Learning aim B: Understand the operation of programmed electronic ignition and distributorless ignition systems		
B.P3 Explain the components and operation of a programmed electronic ignition system. B.P4 Explain the components and operation of a distributorless ignition system.	B.M2 Compare the relative advantages and disadvantages of a programmed electronic ignition system with a distributorless ignition system.	
Learning aim C: Know about the function and operation of pulse generators and control modules		
C.P5 Describe the function and operation of a pulse generator. C.P6 Describe the use of two different control modules.	C.M3 Explain how the pulse generator and control module function within ignition systems.	
Learning aim D: Be able to undertake tests on electronic ignition system to verify system faults		D.D2 Analyse test results to diagnose defects, wear and maladjustment in ignition systems from given data and symptoms.
D.P7 Use appropriate equipment to carry out tests on five components/circuits to verify faults in an electronic ignition system.	D.M4 Suggest methods for dealing with typical faults on the electronic ignition system.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, A.M1, B.M2, C.M3, ABC.D1)

Learning aim: D (D.P7, D.M4, D.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to vehicle workshops equipped with modern vehicles, rigs, components and appropriate test equipment.

For learning aim D, learners should have access to appropriate test and diagnostic equipment to identify faults on at least five different components or circuits (as identified in the unit content). The ignition system and components can be selected by the centre and do not need to cover each of the three types of ignition system from the unit content. Learners must demonstrate safe working when completing any testing or inspection activity.

Essential information for assessment decisions

Learning aims A, B and C

For Distinction standard, learners will need to demonstrate in their evaluation an in-depth understanding of how components contribute to the function and operation of different ignition systems. They need to evaluate the advantages and disadvantages of a conventional ignition system, an electronic ignition system and a distributorless ignition system. The evaluation should include details of the components for each type of ignition system, how they operate and typical applications. For each ignition system the learner should evaluate their performance during cold starts as well as different acceleration situations such as smooth and steady acceleration compared to rapid acceleration for example when overtaking.

For Merit standard, learners need to demonstrate their understanding of the function and operation of components within the context of a conventional ignition system. The explanation should detail how these components contribute to the function and operation of different ignition systems. Learners need to provide information on the advantages and disadvantages of a programmed electronic ignition system and make comparisons with a distributorless ignition system, for example with respect to maintenance requirements or reliability. Learners should then explain how the pulse generator and control modules function within the ignition system with reference to ignition timing, for example during cold starting or when accelerating.

For Pass standard, learners need to provide information on the function and operation of conventional, programmed electronic and distributorless ignition system. For each system they should use labelled diagrams to identify the various system circuits and their components. They need to show their knowledge of different sensors that are included in the various ignition systems along with their function. Learners will the need to describe the function and operation of pulse generators with respect to their use in an electronic ignition system and use of at least two different control modules that are used to control ignition systems.

Learning aim D

For Distinction standard, learners will diagnose most faults and provide analytical responses to defects, wear and maladjustment for at least five components/circuits. Data and typical faults need to be given to each learner, though often learners identify issues and provide considered responses independently, their evidence is presented comprehensively using testing print outs where relevant.

For Merit standard, learners will diagnose a range of faults on at least five components/circuits and provide information on methods of how to resolve these. Data and typical faults need to be given to each learner, though at times learners identify faults independently, their evidence is presented appropriately using testing printouts where relevant.

For Pass standard, learners will diagnose key faults on at least five components or circuits and suggest appropriate ways to deal with these. Data and typical faults need to be given to each learner and their evidence must include test results. Learners should demonstrate safe working practices at all times, including the safe use of tools and equipment and the use of appropriate personal protective equipment (PPE).

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 65: Vehicle Engine Management Systems.

Employer involvement

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

- work experience
- technical workshops involving staff from local automotive organisations
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Identify questions to answer and problems to resolve when verifying faults in an ignition system.
- Working in a team when collaborating with others to work towards common goals when researching ignition systems.
- Organise time and resources and anticipating and managing risks when carrying out tests on electronic ignition system components/circuits.

Unit 64: Function and Operation of Vehicle Petrol Injection Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

Most modern vehicles are fitted with fuel injection systems that enable the engine to work more efficiently and usually also result in greater power and cleaner exhaust emissions. These systems work by forcing pressurised fuel through a tiny nozzle that atomises the fuel, allowing it to burn more quickly when mixed with air. In this unit learners will study a variety of fuel injection systems in order to understand how they operate and the differences between systems. Learners will develop an understanding of the air and fuel supply systems and will gain knowledge of the operation of the engine control systems and components. Learners will also develop knowledge of the equipment and methods used to test, maintain and repair petrol fuel injection systems.

Learning aims

In this unit you will:

A Understand the operational differences of petrol injection systems

B Understand the function and operation of air and fuel supply components and systems

C Understand the operation of electronic control systems and components

D Know the methods used to test, maintain and repair petrol fuel injection systems.

Unit content

Learning aim A: Understand the operational differences of petrol injection systems

A1 Petrol injection system

- Principles of fuel combustion, e.g. composition of atmospheric air, calorific value of fuel, mixture strength and the range of combustibility, influence of air/fuel ratio on engine power output.
- Vaporisation of fuel and cooling effects on charge density.
- Injector layout (single point, multi-point, phased and continuous injection).
- Mechanical and electronic control (open and closed loop systems).
- Specification, e.g. technical improvements relative to performance, emissions and costs.

A2 Fuel injector positioning

- Single/multi-point/common rail/direct injectors.
- Positioning of injector within the induction manifold, e.g. up-stream, down-stream or direct into the cylinder.
- Quality of the homogeny of the charge and volumetric efficiency, e.g. requirements for compensatory enrichment, effects of fuel condensation on manifolds walls.

A3 Stoichiometric and lean burn technology

- Phasing of injection, e.g. induction cycle injection (stoichiometric cycle), compression stroke injection (direct injection, stratified engine operation).
- Fuel injection strategies, e.g. continuous injection, intermittent injection, semi sequential and sequential injection, asynchronous and grouped injection.
- Operational conditions, e.g. cold starting, idling, maximum power; thermal efficiency and the formation of pollutants.
- Exhaust gas composition, e.g. composition of the exhaust gases under rich, lean and stoichiometric conditions,
- Legal requirements.

Learning aim B: Understand the function and operation of air and fuel supply components and systems

B1 Air supply system components

- Air intake tract.
- Air cleaner.
- Air throttle valve (butterfly valve).
- Throttle body.
- Use of an electric throttle, induction manifold and plenum chamber.
- Variable geometry induction manifolds.

B2 Fuel supply components

- Fuel tank construction, e.g. steel with soldered joints, welded joints, moulded plastic, use of internal baffles and swirl pots.
- Electric fuel pump, e.g. vane, roller gear, plunger.
- Valves, e.g. pressure relief, non-return.

- Fuel lines, e.g. accumulator, pipelines, fuel pipe connections, fuel filter.
- Continuous injection mechanical systems.
- Pressure regulator with induction manifold pressure correction.
- Common fuel rail injection (direct injection), e.g. low-pressure supply pump, low pressure sensor, high pressure pump, high pressure injectors, high pressure sensor.
- Methods employed to reduce fuel vapour escape, e.g. charcoal canister, purge control valve.

Learning aim C: Understand the operation of electronic control systems and components

C1 Sensors, switches and actuators

- Sensors, e.g. crankshaft position, camshaft position, coolant temperature, ambient air temperature, fuel temperature, mass air flow (vane type, thermal type (hot wire and hot chip), manifold pressure sensors (manifold absolute pressure (MAP) sensor, exhaust gas oxygen sensor (step response lambda, broad band lambda), engine speed and throttle position sensor.
- Switches, e.g. thermo-time switch, idle speed switch, inertia switch.
- Actuators, e.g. solenoid injectors, variable manifold butterfly actuators, electrical throttle valve actuator.

C2 Electronic control unit (ECU)

- Input and output processes.
- Injector driver circuits.
- Fuel mapping.
- Basic programming theory, e.g. use of input parameters to enable the software to calculate correct fuel quantity for injection.
- Software updating, e.g. use of specialised software to change fuel map setting at varying engine/operational conditions.
- Software self-diagnostics.
- Controller area network (CAN) data bus, e.g. single wire, twin wire, fibre optic.

C3 Emission control principles and components

- Exhaust gas oxygen sensing; catalytic converter, e.g. reduction, oxidising, nitrogen oxides (nox).
- Exhaust gas recirculation (EGR) and components, e.g. outline of the process to reduce nox formation, operation strategies, EGR valve, vacuum modulator, vacuum sensing valve.
- Air injection and components, e.g. air pump, air injector, pulse air injection, electronic control of EGR and air injection systems.
- Effect of engine operating conditions, e.g. cranking, cold start enrichment, hot start enrichment, cold idle, hot idle, light load, full load, acceleration, deceleration, engine speed limitation.

Learning aim D: Know the methods used to test, maintain and repair petrol fuel injection systems

D1 Diagnostic equipment and tests

- Exhaust gas analysis, e.g. use of exhaust gas analysers, lambda values, air/fuel ratio, idle speed adjustments.
- On-board diagnostics (obd), e.g. fault code reading, data logging, use of break out box to locate faults, data link connection to dedicated code readers.
- Vacuum pump, e.g. induction system leakage, simulation of manifold depression to check fuel pressure regulator.
- Multimeter, e.g. system voltage and circuit tests, circuit resistance, circuit integrity.
- Pressure gauge, e.g. fuel line pressure and regulator settings.
- Injector delivery and spray pattern, e.g. injection quantity, spray pattern and leakage.
- Oscilloscope, e.g. engine/camshaft speed sensor patterns, injection duration, lambda sensor output.

D2 Injection systems faults and symptoms

- Sensor faults, e.g. throttle position sensor, mass air flow sensor, coolant sensor, crankshaft/camshaft speed/position sensor, exhaust oxygen sensor, idle speed control valve.
- Injector faults, e.g. clogged injectors, dirty injectors, leaks, injectors not opening/closing.
- Symptoms, e.g. engine knocking or vibrations, poor engine performance, poor fuel economy, smell of fuel, misfires.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the operational differences of petrol injection systems		ABC.D1 Evaluate two typical modern petrol injection systems in terms of their legal, environmental and operational requirements.
A.P1 Explain the operation of two different petrol injection systems used on modern fuel injected engines. A.P2 Describe the principles of stoichiometric and lean burn technology with reference to petrol injection engines.	A.M1 Compare the injection, combustion cycle and exhaust emissions within a stoichiometric air fuel ratio engine and a lean burn stratified charge engine.	
Learning aim B: Understand the function and operation of air and fuel supply components and systems		
B.P3 Explain the function and operation of the air and fuel supply components of a given fuel injection system.	B.M2 Analyse the function and operation of the air and fuel supply components of a given fuel injection system.	
Learning aim C: Understand the operation of electronic control systems and components		
C.P4 Describe the function and operation of four major input sensors, their related switches and actuators. C.P5 Explain how the electronic control unit uses feedback from these devices to calculate quantity of fuel injected.	C.M3 Explain the emission control measures and associated components used for a given fuel injected engine system.	

Cont.

Pass	Merit	Distinction
Learning aim D: Know the methods used to test, maintain and repair petrol fuel injection systems		
D.P6 Describe the diagnostic equipment required and tests that need to be carried out to check the satisfactory operation of two different fuel injection systems.	D.M4 Explain the symptoms associated with three different injection system faults found in modern engines and the repair strategy for each.	D.D2 Evaluate the use of diagnostic tests in comparison to dedicated on board diagnostic facilities, equipment.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, B.P2, B.P3, C.P4, C.P5, A.M1, B.M2, C.M3, ABC.D1)

Learning aim: D (D.P6, D.M4, D.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a range of components, assemblies and rigs and, wherever possible, to the diagnostic equipment identified in the unit content. Access to suitable vehicles and tools will need to be provided along with a range of relevant information sources and operational manuals.

Essential information for assessment decisions

Learning aims A, B and C

For Distinction standard, learners will need to evaluate two given petrol injection systems. The evaluation should consider two different types of injection system, typically one for a stoichiometric air fuel ratio engine and the other a lean burn stratified charge engine. The evaluation should compare the two injection systems in terms of the operational requirements of the engines, referring to the operating principles of each system and the air and fuel supply components associated with them. Learners need to include details of how each system meets relevant national and international legal and environmental requirements as well as operational requirements. The evaluation must refer to input sensors, switches and actuators and how these contribute to the function and operation of the fuel injection system.

For Merit standard, learners need to compare the injection, combustion cycle and exhaust emissions for a stoichiometric air fuel ratio engine and a lean burn stratified charge engine. They will need to compare the combustion of fuel within an engine and the differences between the homogenous/stoichiometric charge and the stratified, overall lean mixtures associated with modern direct injected engines. Learners need to consider the injector strategies for the two types of engine, including reference to the fuel injector position and layout for an induction port injection and a direct injection into the cylinder.

Learners will need to analyse the function and operation of the full range of air supply components and fuel supply components for a given fuel injection system. The analysis should consider the components individually, and also in combination with respect to the operational requirements of the fuel injection system. They will also need to explain the emission control measures and associated components used for one given fuel injected engine system. Learners should consider the components of the system, including sensors, switches and actuators, and how these work with the electronic control unit (ECU) to control the emissions from the engine when under different types of loading, for example acceleration and idling.

For Pass standard, learners need to provide information on the operation of two different petrol injection systems used on modern fuel injected engines. Learners will need to explain the principles of combustion, vaporisation of fuel and cooling effects on charge density, injector layout, mechanical and electronic control and consider the specifications of each where appropriate. Learners need to explain the principles of stoichiometric and lean burn technology with reference to petrol injection engines. This should include phasing of injection, fuel injection strategies, operational conditions, thermal efficiency and the formation of pollutants including exhaust gas composition. It is expected that learners will refer to more than one type of petrol injected engine to cover the requirements of the unit content.

Learners need to explain the function and operation of the air and fuel supply components of a given fuel injection system. The function and operation of all components listed in content area B1 (air supply system components) should be explained. The fuel supply components should include the tank, pump, valves, fuel lines etc where applicable in the given system.

Learners need to describe the function and operation of four major input sensors, their related switches and actuators and how the electronic control unit uses feedback from these devices to calculate quantity of fuel injected. Learners will also need to describe open and closed loop control methods and their relevance to the function, operation and fundamental principles affecting fuel delivery. In their descriptions, learners need to include details of the interrelationships between each major input sensor considered and other components within the systems. They then need to explain how exhaust gas sensing, catalytic converter, EGR and associated components and the effect of engine operating conditions on emissions.

Learning aim D

For Distinction standard, learners will evaluate the use of diagnostic tests using a range of diagnostic equipment for diagnosing fuel injection system faults. They will need to evaluate the process against the use of onboard diagnostic systems to check for satisfactory operation of two fuel injection systems. The evaluation should consider results that are obtained from each approach and how these results are used to identify repair strategies for the fuel injection system.

For Merit standard, learners need to provide information on symptoms that are associated with three injection system faults, for example explaining that an engine misfire and inconsistent engine power are likely to be associated with a dirty fuel injector. For each of the diagnosed faults learners will need to suggest an appropriate repair solution that could restore the fuel injection system to working order.

For Pass standard, learners need to focus on system defects, symptoms and the necessary testing procedures used in maintenance and repair processes. Learners will need to describe the test processes and equipment that will be needed to check for at least three faults associated with the two fuel injection systems. Learners should include how to use diagnostic equipment such as OBD, vacuum pump, multimeter, pressure gauge, injection delivery and oscilloscopes.

Links to other units

This unit links to:

- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 65: Vehicle Engine Management Systems.

Employer involvement

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

- work experience
- technical workshops involving staff from local automotive organisations
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Reflecting when setting goals with success criteria for their development and work.
- Working in a team when collaborating with others to work towards common goals when researching petrol injection systems.
- Managing self when organising time and resources and prioritising actions.

Unit 65: Vehicle Engine Management Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

Engine management systems have developed in line with technological advances in vehicle electronics and mechanical improvements to engines. These changes have seen engine management systems go from the early mechanical systems, through the development of electrical sensor-controlled systems to the fully integrated engine management systems used in current vehicles.

Engine management systems are now complex and contain a number of previously separate systems. The inclusion of emission control, integrated ignition, transmission drive control and body management systems have made the modern engine management system a complex part of a total vehicle control system. This allows the vehicle to control power, acceleration, and deceleration to allow for drivability, safety, and reliability.

It is important that all motor vehicle technicians are aware of these systems and can recognise and confirm faults on them. This unit will enable learners to understand the fundamental operating principles of vehicle engine management systems and will give them the knowledge and understanding needed to carry out accurate diagnosis and repair. Learners will develop an understanding of the main components of vehicle engine management systems and their relationship to the efficient operation of the engine systems.

Learning aims

In this unit you will:

A Understand the operating principles and characteristics of an engine management system

B Understand the operating principles of engine management system sensors, actuators and control systems

C Understand the interrelationships and interaction of engine management systems and its sub-components

D Be able to carry out engine management system tests to locate system faults.

Unit content

Learning aim A: Understand the operating principles and characteristics of an engine management system

A1 Operating system and its evolution

- Engine management evolution: initial mechanical control systems; progressive integration; fully integrated control.
- Understanding the systems required within the engine management system and why these are necessary for efficient engine control.
- System features: benefits, cost, performance, safety, convenience, efficiency.
- Systems modelling e.g. diagrammatic representation of system input/process/output, characteristics of open and closed-loop system control strategies used in engine management systems.

A2 Engine management systems

- Fuel management (spark and combustion ignition) systems.
- Ignition control and combined fuel/ignition control.
- Air intake and emission control e.g. mass air flow (MAF) sensor, manifold absolute pressure (MAP) sensor, air temperature, active to reactive system control, such as use of lambda system, knock sensor control, exhaust gas recirculation (EGR) control.
- Direct driver inputs e.g. throttle position, driver mode selection, braking.
- Interaction between engine management and other vehicle systems e.g. sport mode on gearbox selection, body roll control, inbuilt speed limiters, electronic drive control.

Learning aim B: Understand the operating principles of engine management system sensors, actuators and control systems

B1 Operating principles of sensors

- Types e.g. electromagnetic, Hall effect, photoelectric, resistive, inductive, piezo-electric element effect, capacitive.
- factors affecting performance and application e.g. sensitivity, accuracy, linearity, and stability; influence of environmental factors e.g. heat, vibration, moisture, contaminants.

B2 Operating principles of actuators

- For example ignition components such as ignition coils, high tension (HT) components (individual coils, coil on plug), fuel components (idle control valves, cold start devices, electronic injectors, EGR, fuel pumps), variable valve timing control.

B3 Operation of control and communication systems

- control systems e.g. analogue, digital, programmable, non-programmable.
- Engine control unit (ECU) system maps; fuel maps, ignition maps.
- main elements of a digital processing system e.g. central processing unit (CPU), memory devices (such as volatile, non-volatile), buses, input/output ports.
- Principal functions of a digital processing system e.g. multiplexing, controller area network (CAN) systems.

Learning aim C: Understand the interrelationships and interaction of engine management systems and its sub-components

C1 Interfacing and signal processing

- Compatibility between components and systems e.g. temperature and speed sensors, throttle position/drive by wire actuators.
- Characteristics of devices which give rise to the need for signal processing (inductive pick-ups, analogue to digital (AD) and digital to analogue (DA) conversion).
- Control of output devices e.g. energy transfer, power output stages, buffer circuits.

C2 Functional interrelationships

- Location e.g. units and components within the vehicle, position/location of components relative to others in the system.
- Functional relationships between the elements of the system e.g. data input from sensors and electronic control unit (ECU) process to affect actuation.
- Cross system sensor/actuators interactions; coolant, air supply, fuel, ignition, exhaust.

Learning aim D: Be able to carry out engine management system tests to locate system faults

D1 Test components/circuits for satisfactory operation

- Safe working practice e.g. common rail fuel pressures, working with ECU, HT voltage.
- Test equipment e.g. onboard diagnostics, test instruments, voltage drop tester, ECU tester, spark advance and retard tester, diagnostic tester.
- Impact of a component's faults and failure on other components within the system, the operation of the system and on external systems e.g. the effect of speed sensor failure, Lambda sensor fault.
- Components and circuits e.g. fuses, wiring, connectors, injector, coil, ECU, pulse generator, sensors/transducers (such as crankshaft, camshaft, knock), actuators, pressure check (fuel pump), break out box.
- Checking for faults e.g. moisture, dirt, corrosion, fault code reading, gap, data link connection, output and resistance, condition, ignition timing, sensor output, sensor operation, diagnostic data analysis.
- Characteristics of failure e.g. operating conditions (conditions in which the system is operative or inoperative, 'fail-safe' features).

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Understand the operating principles and characteristics of an engine management system</td><td rowspan="6">ABC.D1 Evaluate the operation of mechanical, electrical/ electronic engine management systems with respect to system inputs, operations and outputs and their effect on engine performance.</td></tr>
<tr><td>A.P1 Explain the operating principles and characteristics of engine management systems.</td><td>A.M1 Compare the relative advantages and disadvantages of mechanical engine management and integrated electrical/electronic engine management systems.</td></tr>
<tr><td colspan="2">Learning aim B: Understand the operating principles of engine management system sensors, actuators and control systems</td></tr>
<tr><td>B.P2 Explain the operating principles and application of different types of engine management system sensor.
B.P3 Explain the operating principles and application of different types of engine management system actuator.
B.P4 Explain the operating process of the engine management control units and communication systems.</td><td>B.M2 Analyse how the three stages of the engine management system operate (input, processing, outputs) to control the engine.</td></tr>
<tr><td colspan="2">Learning aim C: Understand the interrelationships and interaction of engine management systems and its sub-components</td></tr>
<tr><td>C.P5 Describe the interfacing and signal processing requirements of two engine management system components.
C.P6 Explain the functional interrelationships and system interactions of engine management system units and components.</td><td>C.M3 Explain the benefits of an integrated control system on engine efficiency and performance.</td></tr>
</table>

Pass	Merit	Distinction
Learning aim D: Be able to carry out engine management system tests to locate system faults		
D.P7 Use appropriate equipment and tests to establish serviceability of different engine management system components/circuits. D.P8 Carry out diagnostic checks to locate engine management system faults.	D.M4 Use appropriate equipment and tests to collect and record system data to diagnose engine management system faults.	D.D2 Analyse test results against expected data readings to diagnose system faults where there is more than one area of failure.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, B.P2, B.P3, C.P4, C.P5, D.P6, A.M1, B.M2, C.M3, ABC.D1)

Learning aim: D (D.P7, D.P8, D.M4, D.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a suitably equipped workshop environment that will allow them to complete the practical assessments required in this unit. Learners would also benefit from having access to suitable engine management systems for identification and testing purposes.

Essential information for assessment decisions

Learning aims A, B and C

For Distinction standard, learners will need to evaluate how system components contribute to the function and operation of mechanical and integrated electronic/electrical engine management systems. The evaluation should consider the advantages and disadvantages of each system with respect to inputs, processes and outputs and how these affect engine efficiency and performance, including emission control and fuel management during different operating and environmental environments.

For Merit standard, learners need to compare how components contribute to the function and operation of both mechanical and integrated engine management systems. The evidence should also show that learners have understood the relevant aspects of the engine management system being considered. This should include integration developments, the interaction between other vehicle systems, fuel management systems, ignition control and combined fuel/ignition control, emission control and vehicle performance monitoring.

They need to develop their advantages and disadvantages statements by analysing how the three system stages (input, control, and output) successfully control the engine, for example referring to sensor inputs, engine mapping and controlling fuel system actuators. This could be developed into an explanation of the benefits of an integrated control system with respect to fuel, emission, and performance control. Learners need to explain efficiency improvements that link to the integrated systems and how this robust management of the engine has improved performance.

For Pass standard, learners must explain the operating principles and characteristics associated with an engine management system. The explanation should include systems modelling, details of the control system used and their principle functions and characteristics of at least one mechanical and one integrated electrical/electronic system. Learners need to explain the operating principles of engine management system sensors (such as engine temperature, speed and position sensors), and actuators (such as idle control or ignition components). They also need to explain the operating process of management control units, including the function of system components and how communication systems such as multiplexing work. When considering the operation of sensors, transducers and actuators learners will need to explain their operating principles in the context of three different types of vehicle. Learner evidence should identify, for each specific application, the type of sensor/transducer being used (for example electromagnetic, Hall effect, photoelectric, resistive, inductive, piezo-electric element effect, capacitive), the factors that may affect its performance and application and the influence of environmental factors. For the actuators, learners must show an understanding of the principles of how individual actuators operate, such as spark generation and idle control valve (for example, include how the electromagnetic effect is used to create linear movement).

Learners will also need to describe the interfacing and signal processing requirements of engine management systems. Their description will need to be in the context of two system components and include details of the compatibility between components. The explanation should also induce details of functional interrelationships, such as between sensors and the ECU and system interactions of a fully integrated system.

Learning aim D

For Distinction standard, learners should demonstrate that they are able to use available diagnostic equipment and relevant techniques to diagnose system faults. They should compare test results that they collect with expected data for the systems in order to identify where there is more than one fault in a system.

For Merit standard, learners should undertake diagnostics on an integrated system to identify at least five faults accurately and to supply correction recommendations. They will use appropriate equipment safely and correctly to collect and record system data and then use this information to identify engine management system faults.

For Pass standard, learners will need to use appropriate equipment to carry out tests on five different engine management system components/circuits to establish their serviceability. Learners need to include the results of tests on both components and circuits, and clearly identify which system(s) and components are affected or damaged and those that are serviceable. They will also need to complete checks, for example making use diagnostic equipment, to identify and locate faults in an engine management system. All tests and procedures should be completed to relevant standards and within health and safety guidelines, for example demonstrating safe use of test equipment.

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems
- Unit 64: Function and Operation of Vehicle Petrol Injection Systems
- Unit 67: Operation and Maintenance of Light Vehicle Transmission Systems
- Unit 70: Heavy Vehicle Transmission Systems.

Employer involvement

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

- work experience
- technical workshops involving staff from local automotive organisations
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Reflecting when setting goals with success criteria for their development and work.
- Working in a team when collaborating with others to work towards common goals when researching petrol injection systems.
- Managing self when organising time and resources and prioritising actions.

Unit 66: Light Vehicle Suspension, Steering and Braking Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

Advances in engine and transmission design mean that modern vehicles have an increased need for suspension, steering and braking technology that can cope with the forces associated with modern vehicle performance. Some suspension systems have different modes for the driver to select according to personal demands or those of the terrain. The most sophisticated suspension systems can self-level and have yaw control so that they can adjust to the type of terrain being encountered. Steering systems are now mostly power-assisted, in some cases this is to counter the effects of wider tyres and suspension that have been set to enhance the vehicle's road holding. Most tyres are now low profile in order to ensure that performance, control and stability are maximised. Sports vehicles, family saloons, multi-purpose vehicles, off-road vehicles, passenger service vehicles and large goods vehicles all require different things from these systems in order to perform well in the environment for which they are intended. It is vital that these systems interrelate with, and complement, each other to ensure maximum comfort and safety of the driver and passengers. This unit will develop learners' knowledge of the function and operation of the main suspension, steering and braking system components and their relationship to the efficient operation of the vehicle. Learners will then carry out a range of practical inspection and fault-finding activities on these systems.

Learning aims

In this unit you will:

A Know the function and operation of different types of suspension system

B Know the function and operation of steering system components

C Know the function and operation of braking system components

D Be able to carry out fault-finding procedures on steering, braking and suspension systems.

Unit content

Learning aim A: Know the function and operation of different types of suspension system

A1 Suspension systems

- Suspension requirements e.g. comfort, road holding, sprung weight, unsprung weight.
- Types of independent front suspension e.g. unequal length wishbones, transverse link and strut.
- Types of independent rear suspension e.g. trailing arm, pure and semi, unequal transverse links, transverse link and strut, air suspension.
- Dampers (construction, operation and typical faults).
- Impact of chassis design on suspension type e.g. ladder, monocoque, space frame, welded shell constructions.

A2 Adaptive suspension system main components

- System operation.
- Electronic Control Unit (ECU), regulator; solenoid valve; sensors; dampers, fluid restrictors, magnetic damper fluid.
- Predictive active ride control.
- Working principles of adaptive suspension systems.

Learning aim B: Know the function and operation of steering system components

B1 Steering characteristics

- Understeer; oversteer; neutral steer.
- Roll axis; roll centre; centre of gravity.
- Steering geometry, camber, caster.

B2 Power-assisted steering operation and components

- Hydraulic system operation and components: hydraulic pump; control valve; power cylinder; reservoir; filter; pressure relief valve; pipes; steering gear; types e.g. integral, semi-integral, rack and pinion, worm and follower, speed sensitive.
- Electric power assisted steering operation and components; EPAS steering rack, torque sensor, wiring diagram.

B3 Road wheel construction

- Wheel type e.g. alloy (cast or forged), steel, well based, specialist (such as wire spoke, flat-edge, double hump, divided, detachable flange); rim codes; wheel retention methods.

B4 Tyre construction and application

- Types of tyre construction: radial, cross-ply, run flat.
- Tyre profile and tyre markings e.g. width, aspect ratio, type of construction, load index, speed index, ply ratings, direction indicators.
- Applications e.g. high performance, light vehicles, motorcycle, agriculture, industrial.
- Valve types e.g. snap in, clamp in.
- Tyre pressure monitoring systems.

Learning aim C: Know the function and operation of braking system components

C1 Main components

- Types of system e.g. single piston disc brakes, multi-piston disc brakes; brake fluid characteristics.
- Brake bleeding componentry.
- Brake pad warning systems.
- Types of brake circuits (construction and operation) e.g. tandem master cylinders, vacuum servo units, pressure apportioning valves.
- Handbrake systems; mechanical systems and components; electric control systems and components.

C2 Anti-lock braking system (ABS) and traction control components

- System operation and components; wheel speed sensors; ECU; system modulator; reservoir; electronic control system.
- Dynamic stability control; system function, inputs and outputs.

Learning aim D: Be able to carry out fault-finding procedures on steering, braking and suspension systems

D1 Fault finding

- Using diagnostic equipment to identify typical faults and the corrective action to be taken for each system.
- Adjustment and servicing of the main components for each of the systems
- Protection of components and systems against the usual hazards during use or fault finding.
- Safe working practice.

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Know the function and operation of different types of suspension system</td><td rowspan="8">ABC.D1 Evaluate the impact of different types of suspension, steering and braking systems on the modern driving experience.</td></tr>
<tr><td>A.P1 Describe the function and operation of one independent front and two independent rear suspension systems.
A.P2 Describe the function and operation of the main components of an adaptive suspension system.</td><td>A.M1 Compare the function and operation of an adaptive suspension system to a fixed mechanical suspension system.</td></tr>
<tr><td colspan="2">Learning aim B: Know the function and operation of steering system components</td></tr>
<tr><td>B.P3 Describe the function and operation of the main components of power assisted steering.
B.P4 Describe the construction of three types of tyre construction.</td><td>B.M2 Explain the effect of understeer, oversteer and neutral steering characteristics, vehicle roll axis, roll centre and centre of gravity on vehicle operation and stability.</td></tr>
<tr><td colspan="2">Learning aim C: Know the function and operation of braking system components</td></tr>
<tr><td>C.P5 Describe the function and operation of the components found in a given type of braking system.
C.P6 Describe the operation of the components found in an anti-lock braking and traction control system.</td><td>C.M3 Explain the interaction between the mechanical and electrical components within an anti-lock braking system.</td></tr>
</table>

Cont.

Pass	Merit	Distinction
Learning aim D: Be able to carry out fault-finding procedures on steering, braking and suspension systems		D.D2 Analyse inspection and test results to diagnose and suggest rectification methods for component defects, wear and maladjustment in a steering, braking and suspension systems.
D.P7 Carry out fault-finding procedures on each system; braking, steering and suspension to check for satisfactory operation.	D.M4 Suggest methods to resolve verified faults for light vehicle steering, braking and suspension systems.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, B.P2, B.P3, C.P4, C.P5, C.P6, A.M1, B.M2, C.M3, ABC.D1)

Learning aim: D (D.P7, D.M4, D.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a range of suspension, steering and braking components and equipment for delivery of this unit. Learners will need access to vehicles in order to carry out fault-finding inspections on the three different systems.

Essential information for assessment decisions

Learning aims A, B and C

For Distinction standard, learners will need to demonstrate a comprehensive understanding of the suspension, steering and braking systems that contribute to vehicle stability control. They will need to demonstrate their understanding of how each of the systems contribute to the total vehicle control system and apply this understanding to evaluate how different systems impact on the driving experience, for example evaluating the effectiveness of self-levelling suspensions to provide ride comfort for passengers. Learners should include details in their evaluation of the additional safety and handling characteristics of cars fitted with these systems.

For Merit standard, learners will compare the difference between mechanical suspension systems and the newer adaptive suspension systems in terms of their components and operation. Learners should clearly identify the benefits for each and explain why the adaptive suspension is an improvement on the mechanical only systems. Learners will explain the main characteristics of vehicle steering characteristics and the impact these can have on driver control in a range of situations, for example how oversteer could cause a vehicle to spin. Learners will also need to explain the features of an anti-lock braking system and how they impact on the mechanical braking systems of the vehicle. This should include accurate explanations of how the mechanical and electrical systems interact to provide enhanced braking performance in a range of driving conditions.

For Pass standard, learners need to describe the function and operation of one front and two rear independent suspension systems discussed as well as one adaptive suspension system. In their descriptions learners, should include details of components, and in the case of an adaptive suspension system this should include details of how the components make the system adaptive and how it functions.

Learners will need to clearly describe the operation of a mechanical/hydraulic power steering system and an electric power assisted steering system. Learners need to cover the process of operation of both systems and how assistance is controlled to respond correctly to driver input. Learners will discuss three types of tyre construction, these should be radial, cross ply and run flat. Learners should include details of how handling characteristics of a light vehicle are affected by each type of tyre construction. Learners will be able to clearly demonstrate an understanding of the footbrake systems, including the function and operation of components, and how they have been enhanced by the anti-lock braking components. Learners should clearly identify the improvements in driver control the anti-lock braking system provides. Learners need to demonstrate a knowledge of current mechanical and electronic handbrake systems.

Learning aim D

For Distinction standard, learners should fully analyse test and inspection results from a range of pieces of diagnostic testing equipment, this should include a full diagnostic system ,onboard diagnostics and visual inspections. Learners need to demonstrate they have successfully collected system data and diagnosed system faults suspension, steering and braking systems. At all times learners will demonstrate the safe use of tools and equipment. On completion of the analysis of the test and inspection results, learners will suggest repair procedures that are appropriate to rectify the faults.

For Merit standard, learners need to correctly suggest repair procedures and expected outcomes for a range of given faults seen within the suspension, steering and braking systems. These faults should cover mechanical and electrical faults within each of the three systems. The suggested repair procedures should be suitable for the given fault.

For Pass standard, learners should complete a structured and logical systems fault-finding inspection on light vehicle suspension, steering and brake systems. Learners need to check each component for functionality and make decisions about serviceability and life span. Throughout the fault-finding procedure learners will need to demonstrate that they are able to safely use tools and equipment.

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems
- Unit 64: Function and Operation of Vehicle Petrol Injection Systems
- Unit 67: Operation and Maintenance of Light Vehicle Transmission Systems.

Employer involvement

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

- technical specialist to discuss diagnostics and technology changes
- work experience
- technical workshops involving staff from local automotive organisations
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Reflecting when setting goals with success criteria for their development and work.
- Working in a team when collaborating with others to work towards common goals when researching suspension, steering and braking systems.
- Managing self when organising time and resources and prioritising actions.

Unit 67: Operation and Maintenance of Light Vehicle Transmission Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers the conventional aspects of light vehicle transmission systems, their function, principal components and operating principles. This will include a detailed examination of the three major systems — a vehicle's clutch mechanism, gearbox, and the driveline and final drive systems. Learners will be introduced to the most recent developments in the use of electronics for the control and operation of transmissions systems in both standard production vehicles and motorsport applications. These developments are now frequently integrated into the overall electronic management of the vehicle and can provide significant improvements in terms of driveability, economy and performance. Learners will develop an understanding of the fundamental operating principles of these developments, their integration within transmission systems and their significance in the maintenance of a vehicle's transmission system. Finally, learners will carry out specific tests and checks to identify transmission system faults such as clutch slip, gearbox linkage problems and failing constant velocity joints. Learners will use these tests and checks, together with on-board diagnostic equipment, to maintain a light vehicle's transmission system. This will include the maintenance requirements relating to driver/passenger safety and component reliability.

Learning aims

In this unit you will:

A Understand the operation of a light vehicle clutch mechanism and the function of its principal components

B Understand the operation of a light vehicle gearbox and the function of its principal components

C Understand the operation of a light vehicle driveline system and final drive and the function of its principal components

D Be able to repair and maintain a light vehicle's transmission system.

Unit content

Learning aim A: Understand the operation of a light vehicle clutch mechanism and the function of its principal components

A1 Manual clutch operation and components

- Production clutches (coil and diaphragm spring, single plate, wet and dry types).
- Motorsport clutches (paddle, slipper and multiplate).
- Engagement and disengagement of clutches (single and multiplate).
- Construction and operation of the pressure plate, disc, release bearings, flywheel (including bearings and bushes).
- Constructional design and use of materials (linings, drive plates and friction surfaces, springs).
- Torque calculations and coefficient of friction.
- Power flow (engine power flow, pedal power flow).

A2 Automatic clutch operation and components

- Automatic clutch components.
- Fluid flywheel (impeller, turbine) torque converter (impeller, turbine, stator, one way clutch).
- Operating principles of fluid flywheels and torque converters.
- Evolution of the fluid flywheel to torque converters.
- Addition of a stator.

A3 Operating principles of clutch release systems

- Release systems, e.g. production vehicles (electrohydraulic, hydraulic, mechanical and cable), motorsport vehicles (push/pull and electrohydraulic actuating mechanisms), electronic clutch control.
- Provision for adjustment/self-adjustment.
- Common faults, e.g. wear, misalignment.
- Fault symptoms (slip, drag, judder, overheating).

Learning aim B: Understand the operation of a light vehicle gearbox and the function of its principal components

B1 Types of gearbox

- Manual (single stage, double stage, sliding mesh, constant mesh).
- Automatic (epicyclic gear train, hydraulic control systems).
- Layout, e.g. transverse, longitudinal and transaxle.

B2 Manual gearbox operation and components

- Gearbox operation and power flow (manual transmission, direct shift gearbox).
- Components (bearings, shafts, casing, selector and sealing arrangements).
- Gear ratio characteristics and number of available gears.
- Gear design (spur and helical).
- Gear locking and interlock mechanisms.
- Gear speed synchronisation and engagement mechanisms e.g. sliding mesh, synchromesh, dog type, selector forks.
- Lubrication, e.g. method (splash and pump assisted).

- Soil requirements and types (mineral, synthetic).
- Seals and sealing arrangements (static and dynamic types).
- Selection and engagement methods, e.g. synchromesh and dog type, selector forks, interlocks and linkages, remote control mechanisms, motorsport (sequential, electro-hydraulic).

B3 Operating principles of automatic gearboxes

- Operation and power flow; standard automatic gearboxes, constantly variable transmission (CVT).
- Automatic transmission components; torque converters (lock-up mechanism); epicyclic gear trains (simple and compound), brake bands, multi-plate and unidirectional clutches.
- Power flow paths.
- Function of key hydraulic components (pump, governor, actuators, servos, regulator and shift valves).
- Constantly variable transmission components; drive belt, primary and secondary cone pulleys, forward and reverse clutch assemblies, input/output shafts, planetary gearset.
- Electronic control system including mode selection.

Learning aim C: Understand the operation of a light vehicle driveline system and final drive and the function of its principal components

C1 Operation and components of driveline system

- Drive systems, e.g. two-wheel, four-wheel (transfer box, centre differentials, viscous couplings, differential locks, automatic and manual)
- Propeller and drive shaft arrangement, e.g. single, divided
- Driveline arrangements, e.g. front, rear and four wheel
- Propeller shaft joints, e.g. universal joints, Hooke type and rubber
- Sliding joints
- Alignment and torque capacity of hollow shafts
- Constant velocity (CV) joints
- Inner and outer joint construction, operating conditions (angular limitations and conditions required to achieve constant velocity, basic consideration of balance requirements, alignment and torque capacity of solid shafts).
- Suspension and transmission characteristics giving rise to the requirement for sliding joints and centre prop shaft bearings.

C2 Operation and components of final drive

- Axle types and support arrangements, e.g. transaxles, live, dead and independent.
- Final drive construction.
- Crown wheel and pinion.
- Gear types, e.g. bevel, spiral and hypoid.
- Gear ratio, speed reduction and torque multiplication, driving thrust and torque reaction in the final drive.
- Final drive arrangements for transaxles.
- Live axle bearing types, e.g. semi, three quarter and fully floating.
- Driven front hub arrangements.
- Non-driven front hub arrangements.

C3 Operating principles of differentials

- Differentials, e.g. sun and planetary gears, limited slip systems.
- Differential (effects on torque/speed at the driven wheels, limited-slip differentials).
- Lubrication methods (final drive and rear axles).
- Oil requirements and types (mineral, synthetic).
- Oil seals and sealing arrangements (static and dynamic).

Learning aim D: Be able to repair and maintain a light vehicle's transmission system

D1 Transmission system faults

- Clutch (slip, drag, judder, loss of drive, excessive noise, wear, misalignment, operating mechanism faults).
- Gearbox (gear selection, oil leaks, linkages and fittings).
- Transmission fluid (levels, leaks, gaskets and seals).
- Driveline and finals drives (prop/drive shafts, universal and CV joints, bearings, gaiters and seals).
- Use of diagnostic testing systems, on-board diagnostic (OBD) equipment, reporting methods (inspection records, oral report to supervisor).

D2 Maintenance operations

- Working to manufacturers' maintenance and service procedures, e.g. manuals, job cards, direct supervision, safety recommendations, material handling (protection against dust, oil and chemical exposure).
- National and international laws/regulations regarding control of hazardous substances and appropriate waste disposal.
- Vehicle and system protection (application of four-wheel drive diff locks, lifting and supporting vehicles).
- Maintenance operations (routine and repair due to system failure), e.g. clutch adjustments/alignment, automatic gearbox fluid checks, gearbox oil change, gear selection linkage repair, driveshaft gaiter condition check/replacement, security of mountings and fittings, correct PPE usage.
- Alternative service procedures for adverse condition (vehicles operating in dry, dusty environments, race/rally vehicles and vehicles working in extreme temperature environments).

Assessment criteria

<table>
<tr><th>Pass</th><th>Merit</th><th>Distinction</th></tr>
<tr><td colspan="2">Learning aim A: Understand the operation of a light vehicle clutch mechanism and the function of its principal components</td><td rowspan="5">AB.D1 Justify the use of a specific clutch and gearbox types for two different light vehicle applications in terms of purpose, function and performance.</td></tr>
<tr><td>A.P1 Describe the operation and function of the key components of different types of clutch mechanism.
A.P2 Explain the operating principles and components of a torque converter.</td><td>A.M1 Compare the key components and operating principles of different clutch types.</td></tr>
<tr><td colspan="2">Learning aim B: Understand the operation of a light vehicle gearbox and the function of its principal components</td></tr>
<tr><td>B.P3 Describe the operation of a modern manual gearbox.
B.P4 Explain the operating principle of an automatic gearbox.</td><td>B.M2 Explain the advantages and disadvantages of manual and automatic gearboxes for light vehicles.</td></tr>
<tr><td colspan="2">Learning aim C: Understand the operation of a light vehicle driveline system and final drive and the function of its principal components</td></tr>
<tr><td>C.P5 Describe the function of the principal components in a light vehicle driveline system.
C.P6 Explain the operating principles of a light vehicle's final drive and differential arrangements.</td><td>C.M3 Compare three different light vehicle driveline and final drive arrangements.</td><td>C.D2 Justify the use of a specific type of driveline and final drive arrangement for two different light vehicle applications in terms of purpose, function and performance.</td></tr>
</table>

Cont.

Pass	Merit	Distinction
Learning aim D: Be able to repair and maintain a light vehicle's transmission system		D.D3 Analyse test results to diagnose component defects, wear and maladjustment in a transmission system.
D.P7 Safely carry out inspection and maintenance on a light vehicle's transmission system.	D.M4 Report faults and attribute symptoms to the faults identified.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, B and C (A.P1, A.P2, B.P3, B.P4, C.P5, C.P6, A.M1, B.M2, C.M3, AB.D1, C.D2)

Learning aim: D (D.P5, D.P6, D.M4, D.D3)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a range of transmission types (clutches, gearboxes and driveline/final drives) and their components. A variety of information and data sources specific to the transmission systems will also be required. Learners will need access to the special tools and equipment needed for investigation and routine maintenance of the selected transmission systems as defined in the unit content and assessment criteria.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will need to demonstrate their in-depth understanding of light vehicle applications for the range of transmission systems available. Learners will need to justify their selection of specific types of gearbox and clutch for two different light vehicle applications, for example a family saloon car and a rally car. Learners need to justify where vehicles fitted with manual and automatic transmission systems would benefit the driver.

Learners should justify their choices of clutch and gearbox based on the requirements of the specific vehicles, for example the type of driving conditions that will be encountered, performance requirements in terms of acceleration and maximum speed, and the types of terrain in which the vehicles will be used. Learners should support their justifications with calculations.

For Merit standard, learners need to demonstrate their understanding of the different types of clutch systems available in a range of applications in light vehicles. They must compare a minimum of two different types of clutch. The comparisons could be between a mechanical clutch and a torque converter or two manual clutch types such as a single plate production clutch and a motorsport paddle clutch. The comparisons should include details of the components, operating principles including how the clutches are engaged and disengaged, power flow within the clutches and also common faults associated with each. Learners need to explain the advantages of both manual and automatic gearboxes. Learners need to review these advantages and disadvantages from a number of perspectives; these can include the driver, owner and service technician.

For Pass standard, learners must describe and explain the components and working processes related to a number of mechanical clutches. Learners should include a range of mechanical clutches such as diaphragm clutches, coil spring clutches, single plate and multiplate. Learners should be able to clearly describe the components within each type and how the components work together to creating an operating clutch. Learners need to include details of the evolution from the fluid flywheel to the torque converter. This should include the differences between the two and why the torque converter is more efficient. Learners need to explain the operating principles and processes of the torque converter, how it generates torque and how the components create this torque. Learners need to demonstrate a full understanding of the operation of a mechanical gearbox. Learners need to describe the components and how these components operate to allow gear selection, torque and speed variance and reverse motion.

Particular attention should be paid to describing the selection and synchronisation of the gears when changing gear. The learner should show a basic understanding of an automatic gearbox, its function and main components. The learner should be able to describe power flow through the automatic gearbox and how this can be varied to allow for different gears.

Learning aim C

For Distinction standard, learners will need to justify their selection of specific types of driveline and final drive arrangements for two different light vehicle applications. These can include front, rear or transaxle drive systems. The learner needs to justify their selection in terms of the positives and negatives of each system linking these to purpose, function and performance requirements of the two light vehicles. This could include comments on usability, comfort and fuel economy.

For Merit standard, learners need to compare three types of driveline and final drive arrangements chosen from the content for this section. The learner needs to look at the systems analytically, including details of the principal components of each, and create clear advantages and disadvantages of each of the systems. The learner should then provide a structured conclusion that demonstrates the facts for each and including examples of applications and situations where each system would be the best choice.

For Pass standard, learners need to clearly describe the operation of the main components in a driveline system. This should include the components listed in the content section. Learners need to reflect the different layouts used in light vehicles and how this influences the system components needed. Learners should describe the components used in independent and fixed axle layouts, how the components are linked and how they allow the torque to be distributed around the vehicle. Learners need to demonstrate an understanding of final drive setups through an explanation of their operating process and why the final drive is required. The learner will need to explain the principle of the differential, why is necessary and how it functions to vary the drive to the wheels during vehicle turning manoeuvres.

Learning aim D

For Distinction standard, learners will produce a professional, balanced analysis of test and inspection results to diagnose faults with at least two different types of transmission system. The systems should allow learners to diagnose a range of different types of fault during the servicing and testing/diagnostic activities including those associated with the clutch, gearbox, drive line and final drive. This should result in a written report including reference to the diagnosis of maintenance requirements with respect to component defects, wear and maladjustment of system components. Where appropriate learners should make use of on-board diagnostic equipment, collected data, along with oral reports and inspection records to complete their diagnosis and to identify component serviceability, maladjustment and defects.

For Merit standard, learners need to explain the links between reported symptoms and the system faults that can create them. Learners will need to demonstrate this through workshop activities and generate accurate reports that clearly identify the diagnostic system used to identify the fault correctly.

For Pass standard, learners need to follow maintenance guidelines to service, maintain and adjust components within a range of driveline systems. Learners should complete a full system inspection on a range of driveline systems to include front wheel drive and rear wheel drive live axle. Learners need to follow standard reporting methods for recording the service/maintenance procedures followed and report any faults found during the process with supporting information and/or data.

Throughout the maintenance activity learners will need to demonstrate that they are able to work safely including the correct use of PPE, protect the vehicle from damage and handle and dispose of materials appropriately.

Links to other units

This unit links to:

- Unit 59: Battery Manufacturing
- Unit 60: Electric and Hybrid Vehicle Motors
- Unit 61: Electric Vehicle Drives
- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems
- Unit 64: Function and Operation of Vehicle Petrol Injection Systems.

Employer involvement

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

- technical specialist to discuss diagnostics and technology changes
- work experience
- technical workshops involving staff from local automotive organisations involved with conventional light vehicles and/or motorsports
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Reflecting when setting goals with success criteria for their development and work.
- Working in a team when collaborating with others to work towards common goals when researching transmission systems.
- Managing self when organising time and resources and prioritising actions.

Unit 68: Lean Production System Design

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit aims to develop learners' understanding of the issues and dynamics associated with the design and management of modern production systems.

Industry professionals within engineering companies understand that manufacturing must be seen as a holistic and dynamic system that integrates people, business processes and technology. This unit aims to develop learners' understanding of the issues and dynamics associated with the design and management of modern production systems.

The unit specifically focuses on lean manufacturing – a management philosophy that focuses on the identification and elimination of waste in manufactured products. Lean thinking principles have emerged as a method to improve the flexibility, reliability and profitability of engineering enterprises worldwide. It is being used to reduce inventory, batch size and set-up times. As enterprises have reduced costs and improved quality, the primary competitive measure is the ability to respond to the customer.

This unit first introduces the basic principles of lean (value, value stream, flow, pull, and continuous improvement). The unit will develop these concepts and give learners a full understanding of the skills and competencies required by someone working in a lean manufacturing environment. It then covers lean manufacturing methods and tools designed to put these concepts into practice in a manufacturing environment. Topics explored include flow process analysis, production levelling, Kanban systems, set-up reduction, standard operations, total productive maintenance and autonomous maintenance.

Learning aims

In this unit you will:

A Know the principles of lean manufacturing

B Know how to create a flexible production system

C Be able to apply the single minute exchange of die (SMED) method to a production system

D Know how to implement a total productive maintenance system.

Unit content

Learning aim A: Know the principles of lean manufacturing

A1 Minimising waste

- Definition of waste.
- Areas of waste e.g. operator motion, waiting time, over production, process time, defects, inventory, transportation, definition of value/non-value added activities.
- Streamline flow e.g. goal of streamline flow, impact of smoothing production, assumptions of the economic batch quantity, hidden costs of inventory.

A2 Group technology techniques

- Use of classification system.
- Cluster analysis.
- Cell design.
- Exploiting similarities of products within families e.g. reduced set-ups, smaller batch sizes, improved productivity, reduced inventory, easier handling, standardisation of tasks and equipment, reduced tooling, jigs, fixtures and pallets, simplified production planning and control, improved quality, identification and solving recurring problems, employee job satisfaction.

A3 Continuous improvement principles

- Small incremental improvement steps.
- Benefits over large step changes e.g. sustainable reduction/elimination of the 'seven wastes' and the 'six big losses' of production, reduced cost, improved safety, quality, working practices and procedures.

A4 Visual management

- Local visual management systems.
- Visual display techniques.
- Visual control methods.
- Benefits of visual management.

A5 Pull production systems principle

- Demand-driven production.
- Advantages of pull production e.g. reduced inventory, reduced lead time, improved part synchronisation, elimination of queues, improved defect detection rate.

A6 Workplace organisation

- Correct location for machines, tools, equipment and inventory.
- Point-of-use stock.
- Sort out/clear out.
- Straighten/configure.
- Shine/clean.
- Standardise/conformity.
- Self-discipline/custom and practice.
- 5S/5Cs audits.

Learning aim B: Know how to create a flexible production system

B1 Flow process analysis

- Analysis charts e.g. flow diagrams, multiple-activity charts, man/machine charts, two- handed charts, payback matrix, lead-time analysis, lead time profiles, frequency diagrams.
- Basic mapping procedure e.g. identify area, map current state, examine, develop future state map, implement and repeat.

B2 Production levelling

- Documentation e.g. precedence charts, collecting manual, production schedule.
- Line balancing procedure e.g. walk and machine times, determining customer demand, determining batch size, calculating system cycle time, calculating takt time, calculating number of workstations, assigning tasks.
- Analysis e.g. line balance ratio, line balance efficiency.

B3 Kanban systems

- Types of kanban e.g. production, withdrawal, special, combined, single card system, dual card system.
- Kanban rules e.g. determining the batch quantity, determining the number of kanban.
- Further kanban systems e.g. express production kanban, offline kanban, raw material kanban, supplier kanban, footprint kanban, max/min buffers, two bin systems.

B4 Standard operating procedure (SOP)

- Rules of the standardised job.
- Documentation (standard combination sheets and standardised work charts).
- Key quality and safety points; work elements; element times e.g. manual, walking, machine, cycle, takt; equipment and machine layout.

Learning aim C: Be able to apply the single minute exchange of die (SMED) method to a production system

C1 Single minute exchange of die (SMED)

- Methodology (identify elements, separate internal and external activities, convert internal activities to external, standardisation, reduce internal times, reduce external times, implementation plan).
- Aids (conversion matrix, use of pre-set tooling, special fasteners, manifolds, parallel activities).
- Set-up elements e.g. preparation, mounting and extraction, establishing control settings, first run capability.

Learning aim D: Know how to implement a total productive maintenance system

D1 Total productive maintenance

- Major causes of machine breakdowns; the traditional approach to maintenance.
- Elements of a breakdown e.g. mean time between breakdowns, mean time to repair, availability, activities during machine downtime; principles of total productive maintenance.
- 5C/5S foundations.
- Prioritisation and elimination of the 'six big losses' to production e.g. unexpected breakdowns, set-up and adjustments, minor stoppages, actual operating speed, defects, start- up yield, role of operator and maintenance engineer during 1st and 2nd line maintenance.

D2 Steps to autonomous and planned maintenance

- Establish autonomous maintenance.
- Establish planned maintenance programme.
- Conduct operator and maintenance engineer training.
- Maintain equipment in optimum condition.
- Set up early equipment management programme.

D3 Overall equipment effectiveness (OEE)

- Performance metric and improvement cycle.
- Definition of availability.
- Performance.
- Quality.
- Calculating OEE.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know the principles of lean manufacturing		
A.P1 Describe the principles of minimising waste and the techniques of group technology. A.P2 Describe the principles of continuous improvement and the use of visual management systems. A.P3 Describe the principles of a pull production system and the use of workplace organisation.	A.M1 Explain the benefits of applying group technology to a production system.	A.D1 Compare and contrast the incremental approach to continuous improvement with that of large step changes.
Learning aim B: Know how to create a flexible production system		
B.P4 Use suitable flow process analysis charts and mapping procedures to determine the current state of a production system. B.P5 Perform a production levelling exercise to determine a future state map of a production system. B.P6 Describe a type of kanban system and a further Kanban system, including kanban rules. B.P7 Compile a SOP for one element of a production system.	B.M2 Explain the advantages of smoothing production.	B.D2 Evaluate the issues encountered when applying lean principles to create a flexible production system from a traditional production system.

Pass	Merit	
Learning aim C: Understand the operation and application of a heavy vehicle auxiliary braking system		
C.P8 Apply the SMED to reduce the change over time of one element of a production system.	C.M3 Explain the importance of set-up reduction to the performance of a production system.	
Learning aim D: Be able to maintain the safety of a heavy vehicle's braking system in accordance with legal requirements		
D.P9 Describe total productive maintenance and the steps required for autonomous and planned maintenance. D.P10 Gather production data and calculate the overall equipment effectiveness (OEE) of a production system.		

Essential information for assignments

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

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

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

Learning aim: B (A.P4, A.P5, B.P6, B.P7, B.P8, B.M2, B.D2)

Learning aim: C (C.P8, C.M3)

Learning aim: D (D.P9, D.P10)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to an up-to-date reference library with computer-aided learning resources and appropriate journals.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will need to compare the incremental approach to continuous improvement with that of large step changes. Learners should consider both the business and human sides of managing change in terms of improved efficiencies, working practices, procedures, participation and sustainability of the improvement process.

For Merit standard, learners need to explain the benefits of applying group technology. Learners should be able to provide evidence of an understanding of how parts similarities (in terms of geometry, size, tolerances, material and method of production) can be exploited for the benefit of the production system. M2 requires learners to describe the advantages of smoothing production. To achieve M3, learners need to independently explain the importance of set-up reduction to production system performance. Evidence for all the merit criteria is likely to be through written reports.

For Pass standard, learners will need to describe the areas of waste found in a production system when they are describing the principles of minimising waste for P1. This may be achieved in a number of ways, e.g. a short-written description of the type of waste or by using suitable annotated photographs. Learners are not expected to write lengthy descriptions to achieve this criterion. Learners must also briefly describe the techniques that can be used to identify part families. Ideally this can be expanded to explain the benefits of exploiting the similarities of products within families and used for evidence towards M1. P2 requires learners to explain the principles of continuous improvement and explain how visual management systems can be applied to reinforce and sustain improvements. An assignment could be developed on the two approaches and then linked to D1 by asking learners to compare and contrast the incremental approach to continuous improvement with that of large step changes. P3 requires learners to explain the principles of pull production and its essential prerequisite workplace organisation. This could be achieved via a presentation to the group, or as an annotated poster.

Learning aim B

For Distinction standard, learners need to evaluate the issues encountered when applying lean principles to develop a flexible production system from a traditional system. It is important that centres do not make this over-complex, otherwise learners will not have the time to achieve this. Learners can explain the issues they encountered during their practical exercises, evaluate their improvement methodology and suggest how this may alter their approach to future improvement activities. Learners should show an appreciation of the culture change required to create a modern production system and the practical, managerial and social challenges this presents.

For Merit standard, learners need to describe the advantages of smoothing production. Evidence for this could be gathered either in the form of a short report or by a short presentation.

For Pass standard, learners need to use suitable flow process analysis charts to map the current state of a given production system for P4. They must then perform a production levelling exercise and determine a future state map of the production system (P5). Evidence for these criteria could be provided from the learner's involvement in continuous improvement activities in the workplace or through a work placement. If assessed directly by the tutor, suitable evidence from these activities would be standard documentation and observation records. If assessed during a placement, witness statements should be provided by a suitable representative and verified by the tutor. P5 can be expanded to include M2, where learners describe the advantages of smoothing production. Evidence for this could be gathered either in the form of a short report or by a short presentation. P6 requires learners to describe one kanban and a further kanban system including their rules. Tutors could allocate different kanban systems to individual learners or groups of learners and ask them to feed back to the class through presentations. P7 requires learners to compile a standard operating procedure for one element of a production system. Ideally this should be linked to P4 and be done in the workplace, or possibly as part of a work placement. Assessment evidence for this criterion could take a similar format to that for P4.

Learning aim C

For Merit standard, learners need to demonstrate how M3 could be linked to P8 through the use of a short report, with learners explaining the importance of set-up reduction to the performance of a production system.

For Pass standard, learners must apply the SMED approach to reduce the changeover time of an element of a production system for P8. Standard documentation used to aid the analysis may be used as evidence for this criterion. As some learners may not have real access to this form of activity, simulation could be used. Again, learner evidence could be in the form of a presentation.

Learning aim D

For Pass standard, learners must describe total productive maintenance and the steps required to implement autonomous and planned maintenance for P9. This could be achieved by a written description that should include areas identified in the unit content, from major causes of machine breakdowns, to 5C/5S foundations through to prioritisation and elimination of the '6 big losses' to production.

P10 builds on P9 and asks learners to gather production data and calculate the OEE of a production system. Assessment evidence could come from the learner's involvement in continuous improvement activities in the workplace or through a work placement. Again, as some learners may not have real access to this form of activity, simulation could be used.

Links to other units

This unit links to:

- Unit 3: Product Design and Manufacture in Engineering
- Unit 10: Computer Aided Design in Engineering
- Unit 39: Modern Manufacturing Systems
- Unit 40: Computer Aided Manufacturing and Planning.

Employer involvement

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

- technical specialist to discuss the function and operation of heavy vehicle braking systems
- work experience
- technical workshops involving staff from goods vehicle and passenger vehicle operators
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Research, presentation and formal communication skills.
- Analysis skills when reflecting on a given issue.
- Practical skills when carrying out workshop activities.
- Independent working practices when completing an assignment or task.

Unit 69: Heavy Vehicle Braking Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

The unit will develop learner knowledge and understanding of the specialist braking systems found on heavy vehicles, public service vehicles and heavy plant. Learning aim A will introduce learners to air compression and storage for heavy vehicle braking systems. This will include the operation of the air supply and storage components, together with the function and operation of pressure protection devices such as pressure regulating valves, switches and sensors.

Learning aims B and C will then introduce learners to the actuation, control and operation of heavy vehicle braking and auxiliary braking systems. The final Learning aim will provide hands-on experience of maintaining a heavy vehicle's braking system in accordance with safety and legal requirements. This will include familiarising learners with relevant safety precautions such as braking efficiency, brake balance and pressure build-up time.

Learners will also be introduced to the legislation and regulations that apply to heavy vehicle braking systems. Learners will apply maintenance procedures including drum/disc brake adjustment, brake tests, leakage tests, pressure monitoring and the maintenance of appropriate maintenance records.

Learning aims

In this unit you will:

A Know the function and operation of air compression and storage components in a heavy vehicle braking system

B Know the function and operation of actuation and control systems used on heavy vehicle air brakes

C Understand the operation and application of a heavy vehicle auxiliary braking system

D Be able to maintain the safety of a heavy vehicle's braking system in accordance with legal requirements.

Unit content

Learning aim A: Know the function and operation of air compression and storage components in a heavy vehicle braking system

A1 Air supply and storage

- Air filter, e.g. induction manifold, inlet filter.
- Air compressor, e.g. method of drive, single/twin cylinder, liquid/air cooled air compressor, internal unloading mechanisms.
- Air drier, e.g. single/twin tower air drier, purge tanks.
- Electronic air processing system (APS), e.g. integrated air driers, multi-circuit protection valves, electronic control to adjust reservoir charge pressures.
- Antifreeze system, e.g. alcohol evaporator/injector, heater units on air drier components; safety valve, e.g. location and reasons for fitting.
- Number and size of air reservoirs.
- Testing and inspection.
- Factors that affect serviceability.

A2 Pressure control and protection

- Circuit pressure control and monitoring valves, e.g. single and double check valves, pressure regulating valve, pressure protection valve (single and multi), automatic drain valves.
- Warning devices, e.g. low-pressure warning devices, pressure gauges, pressure switches and pressure sensors.
- Pressure control system, e.g. governor valve and integral un-loader mechanisms in compressor and air drier units, remote un-loader valve.

Learning aim B: Know the function and operation of actuation and control systems used on heavy vehicle air brakes

B1 Actuation system

- Air brake actuators, e.g. single, double and spring brake units (diaphragm and piston types), methods used to release spring tension in the absence of air pressure.
- Parking brake systems, e.g. remote and integrated spring brake units, application with drum and disc brake units.
- Brake clearance adjustment, e.g. slack adjuster (manual and automatic), foundation brake expander mechanisms (wedge, S-cam, strut (Z-cam), disc brake).
- Auxiliary air valves, e.g. quick release valves, solenoid valves, test couplings, manual release valves, exhaust silencing devices.
- Safety precautions and procedures, e.g. risks associated with compressed gas, trapping hands in actuation mechanisms.

B2 Control system

- Foot valve e.g. single and dual units, position within the pneumatic circuit
- Hand control valve, e.g. upright and inverse pressure types, position within pneumatic circuit.
- Relay valve, e.g. function and operation, single and multi-input relay valves, trailer control valve, trailer emergency relay valve, supply dump valve.
- Pressure protection systems, e.g. brake protection valve (for use with vehicles using load sensing and air suspension).
- Interlock valve, e.g. spring brake-parking protection in the event of parking brake lever set in OFF position on the air pressure build up causing the brakes to release.
- Electronic control of air braking, e.g. principles associated with electronic braking systems (EBS), anti-lock braking system (ABS), electronic stability programmes (ESP) and traction control (anti-spin regulation (ASR).

B3 Air braking systems

- Full air system, e.g. service and secondary circuits.
- Split and dual braking systems employing upright and inverse air pressure, differential protection systems for drum brakes employing spring brake units.
- Load sensing valves, e.g. mechanically and pneumatically actuated, adjustment and testing.
- Spring brakes applied to trailers (parking brake circuits).
- Anti-jack knife devices, e.g. causes of jack-knifing, methods to reduce the occurrence, controlled fifth wheel coupling, use of anti-lock braking on tractor drive axle.
- Vehicle configuration, e.g. two-axle and multi-axle layouts (including air suspension, pneumatic circuits, convention for port labelling), 2-line drawbar and articulated vehicle systems.

B4 Air over hydraulic braking systems

- Hydraulic circuit interfaced with air pressure circuits, hydraulically operated expander mechanism, hydraulic tandem master cylinder with air assistance, hydraulic load sensing valves.
- Arrangement of parking brake.
- Use of remote spring brake and application compliance with trailers using full air braking systems.

Learning aim C: Understand the operation and application of a heavy vehicle auxiliary braking system

C1 Engine auxiliary brake

- Exhaust manifold and engine compression types.
- Operational cycle, construction (method used to cut fuel injected), effectiveness, pressure fail safes.

C2 Transmission auxiliary brake

- Hydraulic retarder, e.g. remote and integral construction with gearbox, control system, arrangements for cooling.
- Friction retarder and provision for cooling; electric retarder, e.g. principles (using eddy current braking with reference to Lenz's law), control system, effects of heat generation on the operational efficiency, method used to dissipate heat energy.

Learning aim D: Be able to maintain the safety of a heavy vehicle's braking system in accordance with legal requirements

D1 Safety precautions

- Braking efficiency, e.g. definition, calculation of braking efficiency from data (service, secondary and parking brake test).
- Brake balance, e.g. definition from tester's manual, calculation of brake balance from data obtained under test.
- Pressure build-up time, e.g. definition, test procedure, likely causes of poor build-up performance.
- System inspection and servicing, e.g. daily system checks and procedures, weekly and monthly inspection requirements, driver maintenance routines.

D2 Legal requirements

- Major national and international legal documents affecting heavy vehicle braking standards, e.g. UN ECE Regulation No 13 (Braking), UN ECE Resolution on the Construction of Vehicles (RE3).
- National and international regulations related to Goods Vehicles (Plating and Testing), Public Service Vehicles (Condition of Fitness, Equipment, Use and Certification).

D3 Maintenance

- Drum/disc brake adjustment.
- Brake test, e.g. roller brake testers, use of retardation meter under road test conditions.
- Leakage test, e.g. pressure loss over set time, use of leak detection device/fluids.
- Pressure monitoring, e.g. checking load sensing valve settings, pressure balance on dual footbrake valves, operation of the trailer control valve dump function, trailer relay emergency valve operation.
- Maintenance records, e.g. legal requirements to keep and store records, paper-based records, wall charts, service sheets, defect notices, prohibitions, computer-based service and maintenance logging.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know the function and operation of air compression and storage components in a heavy vehicle braking system		AB.D1 Evaluate the effectiveness of the ABS/EBS systems when controlling skidding and jack-knifing vehicle.
A.P1 Describe the function and operation of the air supply and storage components of a heavy vehicle high pressure braking system. A.P2 Describe the function and operation of the pressure protection components within a heavy vehicle's pressure storage system.	A.M1 Explain the construction of the air supply and storage components of a high-pressure braking system for a heavy vehicle.	
Learning aim B: Know the function and operation of actuation and control systems used on heavy vehicle air brakes		
B.P3 Describe the function and operation of the components used for the actuation and control of a full air braking system. B.P4 Describe the function and operation of a braking system using air over hydraulic control.	B.M2 Compare the construction, operation and application of a heavy vehicle full air braking system with that of an air over hydraulic system.	

Cont.

Pass	Merit	
Learning aim C: Understand the operation and application of a heavy vehicle auxiliary braking system		C.D2 Evaluate the braking force of an air operated service brake and an auxiliary braking system.
C.P5 Explain the operation of an engine auxiliary braking system. C.P6 Explain the operation of a transmission auxiliary braking system.	C.M3 Compare the application and effectiveness of an engine-activated auxiliary braking system with that of a transmission type auxiliary braking system.	
Learning aim D: Be able to maintain the safety of a heavy vehicle's braking system in accordance with legal requirements		D.D3 Diagnose braking faults within the actuation and/or ABS/EBS systems with justification.
D.P7 Carry out and record the results of drum/disc brake adjustment. D.P8 Carry out and record the results of one other heavy vehicle braking system maintenance procedure.	D.M4 Explain the effect that two different types of wear or maladjustment may have on the effectiveness and legality of a heavy vehicle's braking system.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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)

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 vehicle workshop facilities equipped to deal with heavy vehicles. A range of heavy vehicle braking components and rigs will also need to be available.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will need to evaluate how ABS/EBS systems and their components contribute to the function and operation of vehicle braking control and anti-skid and anti-jack knife systems for full air braking systems and air over hydraulic systems. Learners need to evaluate the effectiveness of the operating process in controlling braking pressures and creating stabilised braking. Learners will need to look at two systems used within heavy vehicle technology and compare their operating processes, including the air supply and storage components. Learners will need to evaluate each system for efficiency and usage and make an informed conclusion about both systems.

For Merit standard, learners need to explain how the air supply and storage components function and operate within a high-pressure braking system and how they are constructed to prevent leakage and system failure. Within this explanation the learner should discuss the construction of the storage tanks, their maintenance and service checks. Learners should show an understanding of the pressure tolerance of the components and their potential failure points.

Learners need to compare an air only braking system and an air over hydraulic system, including the working difference, the different components and how these impact on the system efficiency and operation. Learners should be able to include details of the application of the two types of system in modern heavy vehicle applications and why they are suitable.

For Pass standard, learners must describe both the operating principles and characteristics associated with the air supply and storage components of a heavy vehicle high-pressure braking system. This should include examples of locations of the components and how the components work in unison to support the air braking system. Learners should be able to identify the pressure control components needed within the system to prevent overloading or failure control. Learners will need to describe the operation of the pressure control components and how they function.

Learners must also describe the function and operating principles associated with system components for both full air braking systems and the air over hydraulically controlled systems. Learners need to outline the system components and circuits and how the components function to provide and control vehicle braking. Learners should describe the various braking functions of each system including service, secondary and parking brake systems. Learners should discuss the individual components found in each system and where the systems share common components.

Learning aim C

For Distinction standard, learners need to produce an evaluation that details the levels of efficiency and braking force that can be created by a correctly functioning air-controlled service brake and the braking efficiency and force provided by engine and transmission auxiliary brakes. The evaluation should include discussion around the suitability of use for each brake and how this can impact on the driver when using the vehicle. Learners include details of the function and value of each system and its use in modern heavy vehicle technology.

For Merit standard, learners need to compare two main types of auxiliary braking used for heavy goods and passenger carrying vehicle applications. Learners need to compare the efficiency in use of both system and the potential impacts that the correct and incorrect operation of each can have on the vehicle.

For Pass standard, learners must explain both the operating principles and characteristics associated with auxiliary braking systems in applying braking force to the engine and the transmission system. Learners should focus on the theory of operation and how the braking force is applied. Learners need to explain the operation of components used in each system and how these components work. Learners need to discuss any safety systems that are fitted to prevent vehicle damage from incorrect operation.

Learning aim D

For Distinction standard, learners need to demonstrate their ability to use relevant testing processes to diagnose system faults within a range of braking systems as fitted to modern heavy vehicle applications. Learners will need to diagnose faults for a range of systems including the service, secondary and parking braking systems. Learners will need to refer to inspections and maintenance records to support their judgements and consider the effects that the system faults have on the operation of the braking systems.

For Merit standard, learners need to demonstrate their understanding of service and maintenance repair processes for a heavy vehicle braking system. Learners should be able to demonstrate the use of this understanding to be able to diagnose simple faults within the braking system. Learners will need to explain the potential results of two types of system maladjustment or wear. These could include but not be limited to poorly adjusted brakes, work brake shoes/pads, brake imbalance, incorrectly adjusted load sensing valves, worn operating cams etc. Learners need to explain the effect the wear or adjustment failure will have on system operation, vehicle stability and include any related legal implications.

For Pass standard, learners must complete routine servicing and maintenance on both drum brake and brake pad systems. Learners need to record the adjustment completed correctly in line with legal and organisational requirements. The learner should then complete another routine maintenance activity on a further part of the system.

Links to other units

This unit links to:

- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems
- Unit 64: Function and Operation of Vehicle Petrol Injection Systems
- Unit 65: Vehicle Engine Management Systems
- Unit 71: Heavy Vehicle Steering and Suspension Systems, Wheels and Tyres.

Employer involvement

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

- technical specialist to discuss the function and operation of heavy vehicle braking systems
- work experience
- technical workshops involving staff from goods vehicle and passenger vehicle operators
- visits to appropriate automotive organisations to access maintenance facilities and vehicles.

Opportunities to develop transferable employability skills

- Research, presentation and formal communication skills.
- Analysis skills when reflecting on a given issue.
- Practical skills when carrying out workshop activities.
- Independent working practices when completing an assignment or task.

Unit 70: Heavy Vehicle Transmission Systems

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers the conventional aspects of heavy vehicle transmission systems, their function, principal components and operating principles. This will include a detailed examination of a heavy vehicle's clutch mechanism and its gearbox. Driveline and final drive systems including those used for electric and hybrid vehicles will also be investigated. Learners will be introduced to recent developments in the use of electronics for the control and operation of transmission systems in a range of heavy vehicles including both light and heavy goods and passenger carrying vehicles. These developments are frequently integrated into the overall electronic management of vehicles and can provide significant improvements in terms of driveability, economy and performance.

Learners will develop an understanding of the fundamental operating principles of these electronic systems, their integration within heavy vehicle transmission systems and their significance in the maintenance of a vehicle's transmission system. Learners will carry out specific tests and checks to identify transmission system faults such as clutch slip, gearbox linkage problems and failing universal joints. They will use these tests, checks and inspections together with the use of on-board diagnostic equipment, to maintain a vehicle's transmission system. This will include maintenance requirements relating to driver/passenger safety and component reliability.

Learning aims

In this unit you will:

A Understand the operation of a heavy vehicle clutch mechanism and the function of its principal components

B Understand the operation of a heavy vehicle gearbox and the function of its principal components

C Understand the operation of a heavy vehicle driveline system and final drive and the function of its principal components

D Be able to maintain a heavy vehicle's transmission system.

Unit content

Learning aim A: Understand the operation of a heavy vehicle clutch mechanism and the function of its principal components

A1 Principal clutch components

- Pressure plate, disc, flywheel (including bearings and bushes), clutch/driven plate.
- Release bearings, clutch spring, coil springs.
- Release systems, e.g. production vehicle servo mechanisms, air assisted clutch release mechanism.

A2 Types of clutch mechanism

- Production clutches (coil and diaphragm spring, single plate, multi-plate wet and dry types, dual).
- Automatic clutches (torque converter, fluid flywheel, one way clutch).

A3 Operating principles of clutches

- Constructional design and use of materials (linings, drive plates and friction surfaces, springs).
- Engagement and disengagement of clutches (single and multi-plate, one-way clutches, clutch brakes and automatic clutches).
- Provision for adjustment/self-adjustment.
- Torque calculations and coefficient of friction.
- Power flow (engine power flow, pedal power flow).
- Fluid flywheels.
- Common faults, e.g. wear, misalignment.
- Fault symptoms (slip, drag, judder, overheating).

Learning aim B: Understand the operation of a heavy vehicle gearbox and the function of its principal components

B1 Principal gearbox components

- gear design (spur and helical)
- bearings, shafts, casing, selector and sealing arrangements
- gear locking and interlock mechanisms
- gear speed synchronisation and engagement mechanisms e.g. sliding mesh, synchromesh and dog type.

B2 Types of gearbox

- Manual (single stage, double stage, sliding mesh, constant mesh, twin layshaft).
- Auxiliary gearbox (splitter gearboxes, range change gearboxes).
- Automatic and semi-automatic (epicyclic gear train, hydraulic control systems, automated manual transmission.
- Electric and hybrid vehicle gearboxes (helical, dedicated hybrid transmission).

B3 Operating principles of gearboxes

- Manual gearbox – gear ratios, power flow, e.g. constant mesh single and double stage.
- Torque and speed calculations.

- Gear characteristics, e.g. ratio, number of available gears, suitable gear ratios to enable hill climbing ability.
- Gear selection and engagement methods, e.g. synchromesh and dog type, selector forks, interlocks and linkages, remote control mechanisms, automatic gearbox - torque converters (lock-up mechanism).
- Epicyclic gear trains (simple and compound).
- Brake bands.
- Multi-plate and unidirectional clutches.
- Power flow paths.
- Function of key hydraulic components (pump, governor, actuators, servos, regulator and shift valves).
- Electronic control system including mode selection.
- Electronic selection of conventional gear arrangements.
- Electric gearbox and regenerative braking.
- Lubrication, e.g. method (splash and pump assisted); oil requirements and types (mineral, synthetic); seals and sealing arrangements (static and dynamic types).

Learning aim C: Understand the operation of a heavy vehicle driveline system and final drive and the function of its principal components

C1 Principal components of driveline systems

- Propeller shaft arrangement, e.g. single, divided (use of centre bearings).
- Driveline arrangements, e.g. front, rear single and twin and all wheel drives.
- Universal joints, e.g. Hooke type and rubber.
- Constant velocity (CV) joints, sliding joints.
- Drive systems, e.g. two-wheel, four-wheel (transfer box, centre differentials, viscous couplings, differential locks, automatic and manual).
- Driveline retarders/brakes.

C2 Principal components of final drive

- Axle types and support arrangements, e.g. live and independent, single and twin-drive axles.
- Final drives, e.g. bevel, spiral, worm and wheel, hypoid and double reduction.
- Differentials, e.g. sun and planetary gears, crown wheel and pinion.
- Axle types, e.g. three quarter, fully floating and double reduction hub arrangements.
- Bearings and drive shaft loadings.

C3 Operating principles of driveline

- Universal joints.
- Constant velocity (CV) joints (angular limitations and conditions required to achieve constant velocity, basic consideration of balance requirements, alignment and torque capacity of hollow and solid shafts).
- Suspension and transmission characteristics giving rise to the requirement for sliding joints and centre propshaft bearings.

C4 Operating principles of final drive

- Gear ratio, speed reduction and torque multiplication in the final drive.
- Final drive arrangements for transaxles.
- Driving thrust and torque reaction.
- Differential (effects on torque/speed at the driven wheels, limited-slip differentials).
- Lubrication methods (final drive and rear axles).
- Oil requirements and types (mineral, synthetic).
- Oil seals and sealing arrangements (static and dynamic).

Learning aim D: Be able to maintain a heavy vehicle's transmission system

D1 Transmission system faults

- Clutch (slip, drag, judder, loss of drive, excessive noise, wear, misalignment, operating mechanism faults).
- Gearbox (gear selection, oil leaks, linkages and fittings).
- Transmission fluid (levels, leaks, gaskets and seals).
- Driveline and finals drives (prop/drive shafts).
- Universal and constant velocity (CV) joints, bearings, gaiters and seals.
- Use of on-board diagnostic (OBD) equipment.
- Reporting methods (inspection records, oral report to supervisor).

D2 Maintenance operations

- Working to manufacturers' maintenance and service procedures e.g. manuals, job cards, direct supervision.
- Maintenance operations, e.g. clutch adjustments/alignment, gearbox oil change, gear selection linkage repair, driveshaft gaiter condition check/replacement, security of mountings and fittings.
- Context of the maintenance operations, e.g. routine maintenance, repair or adjustment due to a system failure, alternative service procedures for adverse condition (vehicles operating in dry, dusty environments, vehicles working in extreme temperature environments, vehicle operating on un-made roads and rough terrain).

D3 Safety procedures

- Procedures relating to maintenance operations carried out, e.g. materials handling (protection against dust, oil and chemical exposure).
- Vehicle and system protection (application of four-wheel drive diff locks, lifting and supporting vehicles).
- Selection and use of personal protective equipment (PPE).
- National and international regulations related to the control of substances hazardous to health.
- Component and environmental waste disposal electrical hazards.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand the operation of a heavy vehicle clutch mechanism and the function of its principal components		
A.P1 Describe the function of the principal components of two different types of heavy vehicle clutch mechanism. A.P2 Explain the operating principles of one type of heavy vehicle clutch.	A.M1 Compare two different heavy vehicle clutch types in terms of their principal components and operating principles.	AB.D1 Justify the use of a specific clutch and gearbox types for two different heavy vehicle applications in terms of purpose, function and performance.
Learning aim B: Understand the operation of a heavy vehicle gearbox and the function of its principal components		
B.P3 Describe the function of the principal components of one type of heavy vehicle gearbox. B.P4 Explain the operating principles of two different types of heavy vehicle gearbox.	B.M2 Explain the advantages and disadvantages of increasing the number of available gears in a heavy vehicle's gearbox.	

Cont.

Pass	Merit	Distinction
Learning aim C: Understand the operation of a heavy vehicle driveline system and final drive and the function of its principal components		
C.P5 Describe the function of the principal components in a heavy vehicle driveline and final drive. C.P6 Explain the operating principles of a heavy vehicle's driveline and final drive arrangement.	C.M3 Compare two different heavy vehicle driveline and final drive arrangements.	C.D2 Justify the use of a specific type of driveline and final drive arrangement for two different heavy vehicle applications in terms of purpose, function and performance.
Learning aim D: Be able to maintain a heavy vehicle's transmission system		
D.P7 Report faults and attribute symptoms to the faults identified. D.P8 Maintain heavy vehicular transmission system.	D.M4 Suggest methods to resolve verified transmission systems faults.	D.D3 Analyse test results to diagnose component defects, wear and maladjustment in transmission system types.

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, 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)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a range of transmission types (clutches, gearboxes and driveline/final drives) and their components . A variety of information and data sources specific to transmission systems will also be required. Learners will need access to specialist tools and equipment needed for learners to carry out the investigations and routine maintenance operations on the selected transmission systems as defined in the unit content and assessment criteria.

Essential information for assessment decisions

Learning aims A and B

For Distinction standard, learners will produce a professional, balanced justification of their selection of specific types of gearbox and clutch for two different heavy vehicle applications, for example one commercial goods vehicle and one passenger transport vehicle.

Learners should justify their choices of clutch and gearbox based on the requirements of the specific vehicles, for example the type of loads that will be transported as well as the performance requirements for the vehicle in terms of acceleration, maximum speed, range and payload. Calculations should also be used to support justifications. Justifications should also consider the types of roads and highways that the vehicles will travel on and the purposes of the journeys they will make, for example long distance goods haulage on well-maintained roads compared to local transport between towns and villages where passenger vehicles might travel slowly on rough roads through terrain that is hilly and need to stop frequently for passengers.

Overall, the justification will use correct technical engineering terms and will be written in a way that is easy for a third party, who may or may not be an automotive engineer, to understand.

For Merit standard, learners will compare two different heavy vehicle clutch types, for example one automatic clutch such as a torque convertor and one production clutch such as a multi-plate wet clutch. The comparisons should include details of the principal components of each, including the clutch and friction plates as well as bearings and other components. Learners will also need to compare the operating principles of the two different types of clutch, including details of how they are engaged and disengaged, the power flow within each type of clutch and also the common faults associated with each.

Learners will need to demonstrate their understanding of the operation of a heavy vehicle's gearbox by explaining the advantages and disadvantages of increasing the number of gears available. They should refer to gear ratios, including those that are suitable for climbing hills and for use in other terrains. The explanation should be supported by torque and power calculations. Learners will need to explain the effects on the operation of the gearbox whether it is manual or automatic.

For Pass standard, learners will provide evidence describing, for example, the function of the principal components of a single plate production clutch and a fluid flywheel. Having described the components of these two types of clutch they should then concentrate on explaining the operation of one of these in the context of a heavy vehicle.

Similar evidence would also be required for the function and operation of heavy vehicle gearboxes. Learners could provide a description of the principal components such as the gears, locking and interlocking mechanisms as well as synchronisation and engagement mechanisms. Learners should then explain the operating principles of this gearbox alongside a further type of gearbox such as an automatic, or, if appropriate, one that is used in a hybrid or electric vehicle.

Learner evidence may contain some errors in the engineering terminology used, and the descriptions and explanations may be basic in parts. There must be a clear demonstration of knowledge and understanding of relevant heavy vehicle clutches and gearboxes.

Learning aim C

For Distinction standard, learners will produce a professional, balanced justification of their selection of specific types of driveline and final drive arrangement for at least two specific and contrasting heavy vehicle applications, for example one commercial goods vehicle and one passenger transport vehicle.

Learners should justify their choices of driveline and final drive based on the requirements of the specific vehicles, for example the type of vehicle and its use, such as a heavy vehicle transporting goods between rural villages or a passenger vehicle transporting people between towns and cities. The justification should also consider the types of journey that the vehicles will be used for, the terrain, the conditions in which the vehicles will operate and the requirements of the vehicles in terms of loads, speed and acceleration. Overall, the justification will use correct technical engineering terms and will be written in a way that is easy for a third party, who may or may not be an automotive engineer, to understand.

For Merit standard, learners will compare two different heavy vehicle driveline and final drive arrangements, for example one two-wheel drive system used in a heavy passenger vehicle and an all-wheel drive system such as could be found in a heavy commercial tractor unit. The comparisons should include details of the principal components of each driveline system and final drive. Learners will also need to compare the operation and operating principles of the drivelines and final drives, including the relationship between the vehicle's suspension and transmission with respect to the driveline.

For Pass standard, learners will provide evidence describing, for example, the function of the principal components of a twin-drive rear axle system and related driveline system. The description should be comprehensive and cover the majority of components in the driveline and final drive including propeller and driveline arrangements, universal joints, constant velocity joints, axle types, final drives, differentials and drive systems. Learners also need to explain the operating principles of the driveline and final drive and should include details of the function of components including universal and constant velocity joints, gear ratios, final drive arrangements. The explanation should also consider lubrication requirements including requirements for oil, methods of lubrication and sealing arrangements.

Learner evidence may contain some errors in the engineering terminology used, and the descriptions and explanations may be basic in parts. There must be a clear demonstration of knowledge and understanding of relevant heavy vehicle drivelines and final drives.

Learning aim D

For Distinction standard, learners will produce a professional, balanced analysis of test and inspection results to diagnose faults with at least two different types of transmission system. The systems should allow learners to diagnose a range of different types of fault including those associated with the clutch, gearbox, drive line and final drive. Learners should be able to diagnose maintenance requirements with respect to component defects, wear and maladjustment of system components. Where appropriate learners should make use of on-board diagnostic equipment along with oral reports and inspection records to complete their diagnosis, for example one commercial goods vehicle and one passenger transport vehicle.

Overall, the analysis of the test results will use correct technical engineering terms and will be written in a way that is easy for a third party, who may or may not be an automotive engineer, to understand.

For Merit standard, learners will use the results of tests and inspections to suggest suitable methods to resolve faults that have been identified and verified through inspection of different components in heavy vehicle transmission systems. Learners should make their suggestions based on the symptoms that have been reported and the faults that have been identified. Faults should consider the whole of the transmission system including the clutch, gearbox, driveline and final drive.

For Pass standard, learners will provide evidence of being able to report faults related to heavy vehicle transmission systems, including those associated with the clutch, gearbox, driveline and final drive. They will be able to give examples of faults and attribute typical symptoms to the faults they report, for example clutch judder being a symptom of contamination of the clutch plates and give possible causes of the contamination.

Learners also need to demonstrate that they are able to complete maintenance operations on a heavy vehicle transmission system. To achieve this, they will need to show that they are able to follow manufacturers' maintenance and servicing procedures to complete maintenance activities such as a gearbox oil change or checking the condition of driveshaft gaiters and replacing as required. Throughout the maintenance activity learners will need to demonstrate that they are able to work safely including the correct use of PPE, protect the vehicle from damage and handle and dispose of materials appropriately.

Learner evidence may contain some errors in the technical terminology used, and the descriptions of symptoms may be basic in parts. There must be a clear demonstration of safe working practices when completing maintenance operations.

Links to other units

This unit links to:

- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems
- Unit 64: Function and Operation of Vehicle Petrol Injection Systems
- Unit 65: Vehicle Engine Management Systems
- Unit 69: Heavy Vehicle Braking Systems
- Unit 71: Heavy Vehicle Steering and Suspension Systems, Wheels and Tyres.

Employer involvement

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

- guest speakers
- technical workshops involving staff from local operators and maintenance organisations involved with both passenger and commercial heavy vehicles
- contribution of ideas to unit assignments
- access to maintenance facilities and vehicles for teaching and assessment activities.

Opportunities to develop transferable employability skills

- Research, presentation and formal written communication skills.
- Analysis skills when reflecting on a given issue.
- Practical skills when carrying out workshop activities.
- Independent working practices when completing an assignment or task.

Unit 71: Heavy Vehicle Steering and Suspension Systems, Wheels and Tyres

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

This unit covers vehicle steering and suspension systems, their principal components and operating principles. This includes a detailed examination of the steering system including hydraulic power assistance, a variety of suspension layouts currently used on heavy vehicles, such as the leaf, rubber and pneumatic suspension systems.

Learners will be introduced to different heavy vehicle body designs and types that are used to meet the diverse and varying operational conditions experienced by goods vehicles and passenger carrying vehicles. Finally, learners will carry out tests and checks to identify steering and suspension system faults such as failure of power assistance or excessive tyre wear.

Learners will use these tests and checks, together with the legal requirements relating to the class of vehicle, to identify ways to maintain the vehicle's roadworthiness, including the maintenance requirements relating to driver/passenger safety and component reliability. They will then carry out three maintenance tasks, one on each type of system.

Learning aims

In this unit you will:

A Know the construction and operation of heavy vehicle manual and power-assisted steering systems

B Know the types of heavy vehicle body design and suspension systems

C Understand the construction, design and legal requirements for heavy vehicle wheels and tyres

D Be able to carry out maintenance procedures on a heavy vehicle's steering and suspension systems.

Unit content

Learning aim A: Know the construction and operation of heavy vehicle manual and power-assisted steering systems

A1 Manual steering system operation

- Single and twin steer axles, e.g. all connective linkage and geometry to obtain true rolling when cornering.
- Rear axle steering systems applied to large heavy vehicles.
- Steering systems on articulated passenger vehicles.
- Application of Ackermann steering principles to large vehicles.
- Effects of imposed loads on the steering compliance when cornering.
- Effects of load on the accuracy of steering settings.

A2 Manual steering components

- Steering boxes, e.g. recirculating ball, hourglass worm and roller.
- Steering linkage on single and twin steering systems, e.g. drag links, cross shaft, track rods, drop arms, ball joints, king pins and bushes.
- Steering wheels and columns, e.g. use of universal joint to facilitate cab tilting, ergonomic and anthropometrical factors of steering wheel position with or without power-assisted steering.

A3 Power-assisted steering system operation

- Single and twin steer vehicles.
- Integral type power-assisted steering boxes.
- Externally fitted power rams and strut type reaction member.
- Methods employed to apportion power-assisted steering, e.g. torsion bar and rotary hydraulic valve, shuttle type.
- Principles underpinning the method of obtaining power-assisted steering.
- Electric power steering systems.

A4 Power-assisted steering components

- Hydraulic pump (type, position and operation).
- Drive arrangements.
- Pump reservoir.
- Pressure control valves, e.g. pressure relief, flow control.
- Pipes, hoses, seals and gaiters.
- Integral and external power servo rams.
- Filtration.
- Prevention of moisture and dirt ingress, e.g. fluid cleanliness, checking fluid filters and reservoir condition, periodic replacement of hydraulic fluid, bleeding of the system.

A5 Steering geometry

- Non-steer, e.g. wheel alignment requirements of single- and twin-drive axles.
- Steering geometry, e.g. caster, camber, king pin inclination, positive and negative off-set.
- Wheel alignment checks on single and twin steer, e.g. methods used to measure correct alignment between twin steer axles, effects of vehicle load on the accuracy of the settings.

Learning aim B: Know the types of heavy vehicle body design and suspension systems

B1 Chassis and cab design

- Rigid and articulated vehicles.
- Trailer systems, e.g. semi and draw bar trailers; axle layouts, e.g. two, three and four axle vehicles.
- Drive arrangements, e.g. twin drive and all-wheel drive.
- Body types, e.g. flat bed, tankers, refrigerated, box, curtain side, tipper, municipal waste disposal, bus/coach.
- Ergonomics of cab design, e.g. vibration control, instrument positioning, driver controls and facilities.

B2 Leaf spring suspension system

- Springs, e.g. fixed and variable rate, helper springs.
- Centre bolt.
- Bump stops.
- Shackles, e.g. fixed, swinging, shackle pins and bushes, leaf eyes.
- Load compensation mechanisms e.g. balance beam, interactive linkages.
- Transmission of torque.
- Axle location, e.g. use of torque rods, A-frames, Panhard rods, trunnion bearing assemblies.
- Vibration dampers, e.g. function and location.
- Single and double acting telescopic hydraulic dampers.
- Trailing arm suspension.
- Independent suspension, e.g. double wishbone, anti-roll bars.
- Forces acting on suspension members, e.g. reactive and non-reactive systems.

B3 Rubber suspension

- Layout, e.g. configuration of suspension unit to provide energy absorption (positioning in compression and shear).
- Single and multiaxle.
- Methods employed to enable the transmission of braking and driving torque.
- Hub arrangements, e.g. fully floating showing bearing arrangements, prepacked bearing cassettes.
- Lubrication, e.g. type of lubricants and properties, means to ensure adequate lubricant at the contact faces.
- Sealing methods, e.g. use of lip seals, O-rings, sealing compounds.

B4 Pneumatic suspension system

- Axle layout, e.g. two, three, four or more axles.
- Components, e.g. levelling valves, mechanically and pneumatically operated, air suspension.
- Pneumatic circuit components (air springs using double convoluted, involute and rolling diaphragm).
- Axle-lifting equipment, e.g. suspension layout to enable dead axle to be lifted from the road surface, overweight protection, adjustment of trim height.
- Electronic levelling control (ELC), e.g. electronic levelling sensors, control unit, self-diagnosis.

Learning aim C: Understand the construction, design and legal requirements for heavy vehicle wheels and tyres

C1 Construction of heavy vehicle wheels

- Wheel rims, e.g. two-piece, three-piece, one-piece (well-based) rims.

C2 Tyre construction

- Tyre type, e.g. radial ply, cross ply, super single tyres, re-cut tyres, bias belt.
- Tyre inflation valves, e.g. types, remote sensors, position of the valves when fitted to the vehicle.
- Causes and symptoms of defects, e.g. irregular wear patterns, damage to tread, wall and bead region.

C3 Design features of tyres

- Operational factors, e.g. ply ratings, load carrying capacities and load rating index.
- Tubed/tubeless tyres.
- Tread patterns and application, tread depths
- Directional tread patterns.
- Aspect ratios.
- Inflation pressures.

C4 Legal requirements

- Prescribed mixing of tyre construction on large vehicles, fitness for purpose, general condition as prescribed by national and international regulations and relevant vehicle tester's manuals.

Learning aim D: Be able to carry out maintenance procedures on a heavy vehicle's steering and suspension systems

D1 Maintenance

- Removal and refitting of main components.
- Adjustment of main components, e.g. alignment of axles, checking of suspension geometry.
- Servicing/lubrication of main units, e.g. using manufacturers' inspection sheets, awareness of the effects of harsh working environments on the service intervals.
- Personal safety and protection of units against usual hazards during use or repair, e.g. dangers associated with working on air suspension units, overstressing power steering systems during pressure tests.
- Performance tests for the systems, e.g. undertake a manufacturer's test of air suspension or power steering unit.
- Completing report documentation.
- Interpretation of results, e.g. from given data make an interpretation of the systems condition.
- Identification of symptoms and probable causes, e.g. axle mal-alignment, excessive internal leakage in power steering box, failure to self- trim on air suspension, poor handling under load, excessive tyre wear.

D2 Repair cycles

- Preventative and corrective action, e.g. inspection procedures for the different systems (manufacturers' inspection sheets, tester's manual).
- Local, national and international requirements, e.g. for large goods vehicles (LGV), passenger carrying vehicle (PCV).
- Annual tests, e.g. appreciation of the wear limits imposed on components and systems as stated in the tester's manual, inspection of tyres/wheels and the effects of ply/load index on the plated vehicle weights.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Know the construction and operation of heavy vehicle manual and power-assisted steering systems		
A.P1 Describe the operation and components of a manual heavy vehicle steering system. A.P2 Describe the operation and components of a power-assisted heavy vehicle steering system.	A.M1 Compare the constructional details of two different heavy vehicle steering systems.	
Learning aim B: Know the types of heavy vehicle body design and suspension systems		
B.P3 Describe the principles of operation and components of different heavy vehicle suspension systems.	B.M2 Compare the constructional details of two different heavy vehicle body types, layouts and suspension systems.	
Learning aim C: Understand the construction, design and legal requirements for heavy vehicle wheels and tyres		
C.P4 Explain the construction, design features and legal requirements of a heavy vehicle wheel and tyre.	C.M3 Compare two different types and construction of tyre used in heavy vehicles.	ABC.D1 Justify the use of a specific vehicle steering system, suspension system and body construction type for two different heavy vehicle applications in terms of purpose, function and performance.

Cont.

Pass	Merit	Distinction
Learning aim D: Be able to carry out maintenance procedures on a heavy vehicle's steering and suspension systems		D.D2 Diagnose and analyse the cause and effect of defects, wear and maladjustment in a heavy vehicle's steering and suspension systems, including wheels and tyres, from given symptoms and data.
D.P5 Carry out maintenance procedures on heavy vehicle suspension and steering systems.	D.M4 Describe typical repair cycles for heavy vehicle suspension and steering systems.	

Essential information for assignments

The recommended structure of assessment is shown in the unit summary, along with suitable forms of evidence. *Section 6 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, C.P4, A.M1, B.M2, C.M3, ABC.D1)

Learning aim: D (D.P5, D.M4, D.D2)

Further information for teachers and assessors

Resource requirements

For this unit, learners must have access to a range of steering and suspension components and a variety of information and data sources specific to the steering and suspension systems covered. Specialist tools and equipment will be needed for learners to carry out investigations and routine maintenance operations.

Essential information for assessment decisions

Learning aims A, B and C

For Distinction standard, learners will produce a professional, balanced justification of their selection of specific types of suspension and steering systems, body type, layout and types of wheels and tyres for at least two different heavy vehicle applications, for example one articulated twin steer commercial goods vehicle and one single steer passenger transport vehicle.

Learners should justify their choices of steering and suspension systems based on the requirements of the specific vehicles, for example the type of road and terrain in which they will be used, the nature of the loads they will carry and the needs of drivers and operators. Learners will need to justify the body type to be used for the two heavy vehicles and the layout of the vehicles in terms of types and locations of axle.

Learners then need to select and justify types of wheel and tyre for the heavy vehicles. They should consider the construction of the wheel rim for the vehicles, tyre type, inflation methods and operational factors for tyres. The justifications should consider why certain tyre designs may not be suitable for the specific heavy vehicle, for example why a radial tyre is more appropriate for a passenger carrying vehicle than a cross-ply tyre. Overall, the justification of the various systems and components will use correct technical engineering terms and will be written in a way that is easy for a third party, who may or may not be an automotive engineer, to understand.

For Merit standard, learners will compare two different heavy vehicle steering systems, for example a manual single steer system compared with a power-assisted twin steer vehicle. The comparisons should include details of the principal components of each system, including the principles of steering geometry and wheel alignment that would be applicable for single and twin steering heavy vehicles.

Learners also need to compare two different and contrasting vehicle suspension systems for heavy vehicles in terms of their constructional details. The comparison should take in to account the type and purpose of the two vehicles and how the component parts of the suspension systems combine to meet the needs of the specific type of vehicle.

Learners need to demonstrate their understanding of the types and construction of different types of tyre that are used for heavy vehicles. For example, learners could compare and contrast the use of bias belt tyres for heavy duty tipper vehicles that travel on unmade or rough roads compared to radial tyres used for coaches that travel on high quality highways.

For Pass standard, learners will provide evidence describing, for example, the operation and components of a manual single steer system and a power-assisted twin steer vehicle. The descriptions should consider the principles of operation of each of the two systems and how the components in the systems allow them to function correctly. Having described the operation and components of these two types of steering system, learners should then provide descriptions of three different types of heavy vehicle suspension system. Learners should consider at least one rigid vehicle and one articulated vehicle that provide opportunity to describe different body types, for example tankers, tippers and buses. The vehicles should provide an opportunity to describe each of the different suspension types, for example leaf springs for a heavy goods vehicle or a pneumatic suspension system for a bus or coach.

Learners then need to explain the construction, design features and legal requirements of wheels and tyres used on heavy vehicles. Learners should consider the wheel and tyre for one type of vehicle, for example a non-driving axle for a heavy goods vehicle tractor cab unit. The explanation should include the construction of the wheel, the construction and design features of the tyre and how the use of the specific type of tyre meets relevant legal and regulatory requirements.

Learners' written evidence may contain some errors in the engineering terminology used, and the descriptions and explanations may be basic in parts. There must be a clear demonstration of knowledge and understanding of relevant heavy vehicle steering and suspension systems.

Learning aim D

For Distinction standard, learners will produce a professional, balanced analysis of the causes and effects of a range of defects, wear and maladjustment of a number of aspects of a heavy vehicle's steering and suspension systems. Learners must be able to use data and symptoms, either from inspections or maintenance activities they have completed themselves, to diagnose causes of defects, wear and maladjustment. They need to determine and undertake processes for rectification where a component or system deviates from manufacturer's recommendations, data, or regulatory requirements.

Learners need to include within their analysis a justification of the processes required to carry out the rectification procedures. They must cover as a minimum one type of steering system, one heavy vehicle suspension system and one defect for a wheel or tyre.

Where appropriate learners should make use of oral reports and inspection records to complete their diagnosis. The diagnosis should consider at least one commercial goods vehicle and one passenger transport vehicle.

Overall, the analysis will use correct technical engineering terms and will be written in a way that is easy for a third party, who may or may not be an automotive engineer, to understand.

For Merit standard, learners will need to describe the typical repair cycle for both the steering system and suspension systems that have been inspected, for example checking hydraulic fluid levels and operational pressures in a power-assisted steering system. Learners should specify the processes and procedures that need to be followed, referring to manufacturer's manuals and regulatory requirements that may be appropriate. They should include details of symptoms that need to be identified when carrying out these maintenance tasks and the personal safety procedures that should be followed.

For Pass standard, learners need to demonstrate that they are able to complete maintenance operations on heavy vehicle suspension and steering systems. Learners will need to show that they are able to follow manufacturers' maintenance and servicing procedures to complete maintenance activities such as the removal, refitting and adjustment of main system components. Throughout the maintenance activity learners will need to demonstrate that they are able to safely use tools and equipment needed to carry out repairs. This could be achieved through an investigation of a vehicle where learners describe the systems found and the condition of the systems. They then need to carry out maintenance for each system to resolve pre-set faults, damage and defects. Learners should also plan for the maintenance procedures (for example listing the tools required, methods to be used, alignment/adjustment data and the replacement components required) and complete relevant report documentation. There must be a clear demonstration of safe working practices when completing maintenance operations.

Links to other units

This unit links to:

- Unit 63: Operation and Testing of Vehicle Electronic Ignition Systems
- Unit 64: Function and Operation of Vehicle Petrol Injection Systems
- Unit 65: Vehicle Engine Management Systems
- Unit 69: Heavy Vehicle Braking Systems
- Unit 70: Heavy Vehicle Transmission Systems.

Employer involvement

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

- guest speakers
- technical workshops involving staff from local operators and maintenance organisations involved with both passenger and commercial heavy vehicles
- contribution of ideas for unit assignments
- access to maintenance facilities and vehicles for teaching and assessment activities.

Opportunities to develop transferable employability skills

- Research, presentation and formal written communication skills.
- Analysis skills when reflecting on a given issue.
- Practical skills when carrying out workshop activities.
- Independent working practices when completing an assignment or task.

Unit 72: Organisational Efficiency and Improvement

Level: 3
Unit type: Optional
Guided learning hours: 60

Unit introduction

In this unit, learners will gain an understanding of continuous improvement in their sector and identify areas in production where lean working could be used to aid the company. They will learn about quality control methods used in industry and understand the key factors required to remain competitive in the market.

Learners will understand the importance of human resource management in terms of building successful teams and the effect this can have on recruitment and retention of employees.

Learning aims

In this unit you will:

A Understand production activities

B Understand application of quality control and quality assurance

C Understand organisational improvement techniques and competitiveness

D Understand personal rights and responsibilities in an organisation.

Unit content

Learning aim A: Understand production activities

A1 Types of production

- For example mass; flow; automated; batch; one-off.

A2 Considerations

- Market requirements.
- Design of product; plant and equipment availability.
- Plant and equipment layout.
- Personnel; production control.
- Quality control, cost.

A3 Methods and application of cellular and just-in-time (JIT) production

- Relation to modern production requirements.
- Application of push and pull types of production to meet company and customer needs and expectations.

A4 Stages of production planning

- Scheduling, loading, dispatching (coordination of pre-production activities).
- Requirements, e.g. engineering drawings, technical.
- Data, personnel, machinery/tools, components, materials, consumables.

A5 Process charts

- For example flow charts/diagrams, Gantt charts; symbols used in process charts.

Learning aim B: Understand application of quality control and quality assurance

B1 Quality control and assurance

- Meaning of 'quality control' and 'quality assurance'.
- Fitness for purpose, e.g. meeting customer expectations.
- Purchasing.
- Production planning and procedures for quality assurance.
- Manufacture (process control).
- Final inspection and dispatch.
- Statistical Process Control (SPC), e.g. measuring quality/performance, document control as an integral part of quality assurance, records of the correct operation.
- Types and the purpose of sampling, e.g. spot check, random sampling, process sampling, batch sampling.
- Mean time between failures (MTBF) in the context of sample size and frequency.

B2 Inspection

- Checking every stage for deviation from design specification.
- Adjustments that need to be made; stages of inspection, e.g. goods inward.
- During production (process control), final inspection; role of the inspector in.
- Checking compliance with quality standard and procedures; quarantine area to store defective work

B3 BS EN ISO 9001

- Internationally recognised quality assurance standard.
- Role of the quality manual and process/procedures manual.
- Internal/external audits.

B4 Quality manager

- Relationship with other managers/departments in the company.
- Considerations to be made when developing a quality plan, e.g. quality requirements (customer expectations), allocation of responsibilities (at all levels), the setting up of systems to measure quality and report progress, identification and calibration of quality equipment, ability to take corrective actions where necessary.

B5 Total quality management (TQM)

- Main principles and goals.
- Advantages of adopting TQM, e.g. competitiveness in the market, enabling growth and longevity, reducing stress, building teams, partnerships and cooperation.

Learning aim C: Understand organisational improvement techniques and competitiveness

C1 Business Improvement Techniques (BIT)

- Principles of lean manufacture, e.g. removal of waste of all kinds (time, motion, inventory, poor cost of quality etc.), stimulating productivity and quality.
- Use of value-added processes, Kaizen as a philosophy that encompasses continuous improvement.
- Just in time (stockless production or lean production), e.g. manufacturing to order not to stock.
- Kanban inventory control.

C2 Productivity

- Meaning of the term 'production'.
- Benefits to the company of increasing productivity; company, e.g. multinationals, nationals and regional, Small and Medium Enterprises (SMEs) and sole traders.
- Managing the production process, e.g. layout of the production area, batch production, synchronisation, lead-time.

C3 Continuous improvement

- Meaning of 'continuous improvement'.
- Continuous improvement cycle (plan, do, check, and action).
- Benefits gained.
- Flexible working and multi-skilling.
- Importance in the national and global marketplaces, e.g. multinationals, nationals, SMEs and sole traders.

C4 Teamwork

- Roles in a team, e.g. leaders, doers, thinkers, carers.
- Balance in a team.
- What individuals bring to a team; team building.
- Communication in the team.

Learning aim D: Understand personal rights and responsibilities in an organisation

D1 Organisational documentation and employment legislation

- Documentation, e.g. contracts of employment, staff handbook; personnel records, grievance procedures.
- Appraisals.
- Disciplinary procedures.
- National laws/legislation, e.g. employment rights, working time regulations, health and safety at work, data protection, equal opportunities, human rights, equality.

D2 Development and progression opportunities

- Company training programmes.
- Apprenticeships.
- Organisational training opportunities.
- Promotion.
- Transfer.
- Higher education.
- Professional qualifications.

D3 Roles of representative bodies

- For example trade unions, professional bodies, employers' organisations (EEF, the manufacturers' organisation).
- Industry training support.

D4 Investors in People (IiP) national standard

- Four key principles – commitment, planning, action and evaluation.
- How organisations acquire IiP status.

Assessment criteria

Pass	Merit	Distinction
Learning aim A: Understand production activities		
A.P1 Explain the different types of production. A.P2 Describe the requirements that need to be considered when selecting a type of production. A.P3 Describe the different stages of production planning. A.P4 Explain how to apply typical process charts to production planning.	A.M1 Compare the advantages and disadvantages of different types of production.	A.D1 Justify the selection of a production type for a given process.
Learning aim B: Understand application of quality control and quality assurance		
B.P5 Explain the meaning of the terms 'quality control' and 'quality assurance' B.P6 Describe the role and stages of inspection activities. B.P7 Explain the application and content of the BS EN ISO 9000 series of standards. B.P8 Explain the role and responsibilities of the quality manager. B.P9 Describe the requirements of quality planning. B.P10 Describe the principles of total quality management (TQM).	B.M2 Explain the importance of using a structured approach for quality control and quality assurance.	B.D2 Evaluate a quality management process and make suggestions for improvement.

Pass	Merit	Distinction
Learning aim C: Understand organisational improvement techniques and competitiveness		
C.P11 Explain the meaning of the terms Lean Manufacture, Kaizen, just-in-time and Kanban and their overall advantages. C.P12 Explain the importance of improving organisational productivity. C.P13 Describe the need for continuous improvement to ensure organisational competitiveness. C.P14 Describe the key requirements for managing the production process. C.P15 Explain the importance of teamwork and the individual's contribution to effective teamwork.	C.M3 Explain the consequences, for an organisation, of not maintaining continuous improvement standards.	C.D3 Evaluate a production process and identify where improvements can be made to increase productivity and organisational competitiveness.
Learning aim D: Be able to maintain the safety of a heavy vehicle's braking system in accordance with legal requirements		
D.P16 Explain the key features of employment law/legislation in relation to personnel rights and responsibilities. D.P17 Describe the personnel opportunities for development and progression that	D.M4 Explain the effects of not adhering to employment laws/legislation in relation to personal rights and responsibilities.	

Pass	Merit	Distinction
are available in the workplace. D.P18 Describe the role of the representative engineering bodies that support personnel and organisations. D.P19 Explain the implications that laws/policies for good people management have on an organisation and its personnel.		

Essential information for assignments

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

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

Learning aim: A (A.P1, A.P2, A.P3, A.P4, A.M1, A.D1)

Learning aim: B (B.P5, B.P6, B.P7, B.P8, B.P9, B.P10, B.M2, B.D2)

Learning aim: C (C.P11, C.P12, C.P13, C.P14, C.P15, C.M3)

Learning aim: D (D.P16, D.P17, D.P18, D.P19, D.M4)

Further information for teachers and assessors

Resource requirements

Case study of quality management in a sample organisation, for learners with unsuitable employers, to study.

Evidence from previous employment law cases/rulings to allow learners to investigate the importance of an organisation abiding by the law.

Essential information for assessment decisions

Learning aim A

For Distinction standard, learners will need to justify their choice of production type in detail.

For Merit standard, learners need to thoroughly analyse an organisation. Alternatively a case study into quality management of a sample organisation could be used. At least two possible production types should be compared.

For Pass standard, learners will need to identify a range of production processes that could be used to manufacture a product and explain the underlying principles behind them for P1. For P2, learners should identify the customer requirements for a given type of product and describe how these requirements will impact on the selection of a specific production method. For P3, learners would identify the key stages in production planning to produce their production plan for the given product. For P4, learners can add in the need and importance of process charts in the plan to identify key stages in the production.

Learning aim B

For Distinction standard, learners need to identify and evaluate QA procedures in operation and suggest improvements for D2.

For Merit standard, learners need to explain the importance of structure in the quality procedures to gain M2.

For Pass standard, learners need to identify the terms and roles suitable for accurate quality control procedures and how this can be built into TQM for P5, P7, P9 and P10. This could be linked to a case study, based around a company visit if possible. Learners would have to identify the areas where standards such as ISO 9001 are vital in industry and how the companies involved identify the relevant roles for P6 and P8 respectively.

Learning aim C

For Pass standard, learners must analyse different types of production processes and their advantages in improving productivity for P11 and P12. This would then lead to a description of the importance of continuous improvement for P13 and also allow learners the opportunity for detailed discussion to achieve M3 at the same time. Learners should describe a given production process and the importance of the management structures present for P14 and then explain the impact effective team building and teamwork has on productivity for P15.

Learning aim D

For Pass standard, learners must analyse a human resources department including key features and why it is important for companies to follow the law, with some examples of the effects for M4. This could be linked to the importance of representation from bodies such as workers' unions for P18. P17. and P19 can be achieved through research into why companies should continually develop their staff and the effect that Investors in People has on encouraging employment and development.

Links to other units

This unit links to:

- Unit 3: Product Design and Manufacture in Engineering
- Unit 9: Work Experience in the Engineering Sector
- Unit 58: Entrepreneurship and Intrapreneurship in Practice
- Unit 68: Lean Production System Design.

Employer involvement

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

- work experience
- visits to appropriate organisations to discuss legal compliance.

Opportunities to develop transferable employability skills

- Research, presentation and formal communication skills.
- Analysis skills when reflecting on a given issue.
- Practical skills when carrying out workshop activities.
- Independent working practices when completing an assignment or task.

4 Planning your programme

How do I choose the right BTEC International Level 3 qualification for my learners?

BTEC International Level 3 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 3 Certificate or Subsidiary Diploma. Learners who then decide to continue with a fuller vocational programme can transfer to a BTEC International Level 3 Diploma or Extended 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 3 Extended Diploma as the most suitable qualification.

Is there a learner entry requirement?

As a centre, it is your responsibility to ensure that the learners you recruit have a reasonable expectation of success on the programme. There are no formal entry requirements but we expect learners to have qualifications at or equivalent to Level 2.

Learners are most likely to succeed if they have:

- five International GCSEs at good grades and/or
- BTEC qualification(s) at Level 2
- other appropriate qualifications or achievement at year 11 or age 16 in core subjects.

Learners may demonstrate the ability to succeed in various ways. For example, they may have relevant work experience or specific aptitude shown through diagnostic tests or non-educational experience.

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. 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 3 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 3 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 3 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*.

Meeting local needs

Centres should note that the qualifications set out in this specification have been developed in consultation with centres and employers for the relevant sector. Centres should make maximum use of the choice available to them within the optional units to meet the needs of their learners, and local skills and training needs.

In certain circumstances, units in this specification might not allow centres to meet a local need. In this situation, Pearson will allow centres to either make use of units from other BTEC specifications in this suite, or commission new units to meet the need. Centre developed units will need to be quality assured by Pearson at a cost. Centres are required to ensure that the coherence and purpose of the qualification is retained and to ensure that the vocational focus is not diluted.

The proportion of imported, or locally developed units that can be used are as follows. These units cannot be used at the expense of the mandatory units in any qualification.

Qualification	Meeting local needs allowance	Unit equivalence
Diploma (720 GLH)	180 GLH MLN allowed	e.g. 3 * 60 GLH units
Extended Diploma (1080 GLH)	240 GLH MLN allowed	e.g. 4 * 60 GLH units

How will my learners become more employable through these qualifications?

BTEC International Level 3 qualifications are mapped to relevant occupational standards, please see *Appendix 1*: *Links to industry standards*.

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

5 Assessment structure

Introduction

BTEC International Level 3 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.
- All optional units are internally 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. Some units are published separately in the Pearson BTEC International Level 3 Qualifications in Engineering Specification (qualifications.pearson.com/en/qualifications/btec-international-level-3/engineering.html)

We have addressed the need to ensure that the time allocated to final assessment of units is reasonable so that there is sufficient time for teaching and learning, formative assessment and development of transferable skills.

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 3 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 3 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 an M criterion requires the learner to show 'analysis' and the related P criterion requires the learner to 'explain', then to satisfy the M criterion, a learner will need to cover both 'explain' and 'analyse'. The unit assessment grid shows the relationships between the criteria so that assessors can apply all the criteria to the learner's evidence at the same time. In *Appendix 3: 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 3 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 registers with Pearson annually. 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 3: Glossary of terms used*
- examples of assessed work provided by Pearson
- your Lead IV and assessment team's collective experience, supported by the standardisation materials we provide.

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 more than one learning aim (for example A.D1) or to several learning aims (for example DE.D3). 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, produced as a spreadsheet. 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 though 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 tasks.
- 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 3: 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 has a defined degree of control under which it must take place. We define degrees of control as follows.

Medium control

This is completion of assessment, usually over a longer period of time, which may include a period of controlled conditions. The controlled conditions may allow learners to access resources, prepared notes or the internet to help them complete the assignment.

Low control

These are activities completed without direct supervision. They may include research, preparation of materials and practice.

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 learner's work. This may mean that learners be supervised.
- Resources: all learners should have access to the same types of resources 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 Learnermalpractice@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(a)* (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 General and vocational qualifications Suspected Malpractice in Examinations and Assessments*, 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 3 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 3 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, 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.

Compensation table

Qualification	Compensation rule	Unit equivalence
Diploma (720 GLH)	Mandatory must be passed, 180 GLH only at U grade permitted from optional	e.g. 3 * 60 GLH units OR 1 * 60 GLH and 1 * 120 GLH unit
Extended Diploma (1080 GLH)	Mandatory must be passed, 180 GLH only at U grade permitted from optional	e.g. 3 * 60 GLH units OR 1 * 60 GLH and 1 * 120 GLH unit

Calculation of the qualification grade

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

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

BTEC International Level 3 qualifications are awarded at the grade ranges shown in the table below.

Qualification	Available grade range
Diploma	PP to D*D*
Extended Diploma	PPP to D*D*D*

The *Calculation of qualification grade* table, given later in this section, shows the minimum thresholds for calculating these grades. The table will be kept under review over the lifetime of the qualification. In the event of any change, centres will be informed before the start of teaching for the relevant cohort and an updated table will be issued on our website.

Learners who do not meet the minimum requirements for a qualification grade to be awarded will be recorded as Unclassified (U) and will not be certificated. They may receive a Notification of Performance for individual units. The *International Information Manual* gives full information.

Points available for units

The table below shows the number of **points** available for internal units. For each internal unit, points are allocated depending on the grade awarded.

	Unit size	
	60 GLH	**120GLH**
U	0	0
Pass	6	12
Merit	10	20
Distinction	16	32

Claiming the qualification grade

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

Calculation of qualification grade

Applicable for registration from 3 January 2022.

Diploma		Extended Diploma	
720 GLH		1080 GLH	
Grade	Points threshold	Grade	Points threshold
U	0	U	0
PP	72	PPP	108
MP	88	MPP	124
		MMP	140
MM	104	MMM	156
DM	124	DMM	176
		DDM	196
DD	144	DDD	216
D*D	162	D*DD	234
		D*D*D	252
D*D*	180	D*D*D*	270

This table is subject to review over the lifetime of the qualification. The most up-to-date version will be issued via our website.

Examples of grade calculations based on table applicable to registrations from April 2021

Example 1: Achievement of a Diploma with a PP grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int	Pass	6
Unit 3	120	Int Set	Pass	12
Unit 39	60	Int	Pass	6
Unit 57	60	Int Set	Pass	6
Unit 60	60	Int	Merit	10
Unit 61	60	Int	U	0
Unit 62	60	Int	Merit	10
Unit 4	60	Int	Pass	6
Unit 9	60	Int	Pass	6
Unit 8	60	Int	Pass	6
Totals	**720**		**PP**	**74**

The learner has achieved P or higher in Units 1 to 6.

The learner has sufficient points for a PP grade.

Example 2: An Unclassified result for a Diploma

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int	U	0
Unit 3	120	Int Set	U	0
Unit 39	60	Int	Pass	6
Unit 57	60	Int Set	Distinction	16
Unit 60	60	Int	Merit	10
Unit 61	60	Int	Pass	6
Unit 62	60	Int	Merit	10
Unit 4	60	Int	Pass	6
Unit 9	60	Int	Merit	10
Unit 8	60	Int	Pass	6
Totals	**720**		**U**	**76**

The learner has a U in Units 2 and 3.

Examples of grade calculations based on table applicable to registrations from April 2021

Example 1: Achievement of an Extended Diploma with a PPP grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int	Pass	6
Unit 3	120	Int Set	Pass	12
Unit 4	60	Int Set	Merit	10
Unit 5	60	Int	Pass	6
Unit 6	120	Int	Pass	12
Unit 59	60	Int	Merit	10
Unit 61	60	Int	U	0
Unit 62	60	Int	Pass	6
Unit 72	60	Int	Merit	10
Unit 57	60	Int Set	Pass	6
Unit 39	60	Int	Pass	6
Unit 68	60	Int	Pass	6
Unit 65	60	Int	Merit	10
Unit 67	60	Int	Pass	6
Unit 63	60	Int	Merit	10
Totals	**1080**		**PPP**	**122**

The learner has achieved P or higher in Units 1 to 3, 39, 57 & 68.

The learner has sufficient points for a PPP grade.

Example 2: Achievement of an Extended Diploma with a DDM grade

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Pass	6
Unit 2	60	Int	Pass	6
Unit 3	120	Int Set	Distinction	32
Unit 4	60	Int Set	Merit	10
Unit 5	60	Int	Merit	10
Unit 6	120	Int	Distinction	32
Unit 59	60	Int	Merit	10
Unit 61	60	Int	Distinction	16
Unit 62	60	Int	Pass	6
Unit 72	60	Int	Merit	10
Unit 57	60	Int Set	Merit	10
Unit 39	60	Int	Distinction	16
Unit 68	60	Int	Pass	6
Unit 65	60	Int	Merit	10
Unit 67	60	Int	Merit	10
Unit 63	60	Int	Pass	6
Totals	**1080**		**DDM**	**196**

The learner has achieved P or higher in Units 1 to 3, 39, 57 & 68.

The learner has sufficient points for a DDM grade.

Example 3: An Unclassified result for an Extended Diploma

	GLH	Type (Int/Int Set)	Grade	Unit points
Unit 1	60	Int Set	Distinction	12
Unit 2	60	Int	Merit	10
Unit 3	120	Int Set	Distinction	12
Unit 4	60	Int Set	Merit	10
Unit 5	60	Int	Distinction	12
Unit 6	120	Int	Unclassified	0
Unit 59	60	Int	Unclassified	0
Unit 61	60	Int	Merit	10
Unit 62	60	Int	Distinction	12
Unit 72	60	Int	Unclassified	0
Unit 57	60	Int Set	Merit	10
Unit 39	60	Int	Merit	10
Unit 68	60	Int	Merit	10
Unit 65	60	Int	Unclassified	0
Unit 67	60	Int	Merit	10
Unit 63	60	Int	Distinction	12
Totals	**1080**		**U**	**130**

The learner has 240 GLH at U.

The learner has sufficient points for an MPP and has achieved P or higher for Units 1 to 7 but has not met the minimum requirement for 900 GLH at Pass or above.

10 Resources and support

Our aim is to give you a wealth of resources and support to enable you to deliver BTEC International Level 3 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 January 2022) gives you details of the administration of the qualifications and information on the units for the qualifications.

Pearson Progress

Pearson Progress is a new digital support system that helps you to manage the assessment and quality assurance of the Pearson BTEC International Level 3 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 3 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 3 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. 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 study texts across a range of mandatory and optional units to support your students throughout their programme of study.

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 Languages

Pearson provides a full range of support for language learning including diagnostics, qualifications and learning resources. Please see www.pearson.com/languages

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 3 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 3 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 3 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 and automotive areas, 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: 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 Problem solving Analysis Reasoning/argumentation Interpretation Decision making Adaptive learning Executive function
	Creativity	Creativity Innovation
Intrapersonal skills	Intellectual openness	Adaptability Personal and social responsibility Continuous learning Intellectual interest and curiosity
	Work ethic/ conscientiousness	Initiative Self-direction Responsibility Perseverance Productivity Self-regulation (metacognition, forethought, reflection) Ethics Integrity
	Positive core self-evaluation	Self-monitoring/ self-evaluation/ self-reinforcement
Interpersonal skills	Teamwork and collaboration	Communication Collaboration Teamwork Cooperation Empathy/perspective taking Negotiation
	Leadership	Responsibility Assertive communication Self-presentation

Developing the ability to make a persuasive case in the fields of engineering or electrical automotive 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
Client brief	Outlines the client's expectations and requirements for the system.
Explore	Learners apply their skills and/or knowledge to practical testing or trialling.
Examine	Learners are expected to select and apply knowledge to less familiar contexts.
Explain	Learners' work shows clear details and gives reasons and/or evidence to support an opinion, view or argument. It could show how conclusions are drawn.
Integrated Development Environment (IDE)	A specialist piece of software in which computer programs are created. It contains a number of tools to help the programmer code.
Investigate	Learners' work tests the following through practical exploration: · qualities of materials · techniques processes or contexts.
Microcontroller	Contains all the internal components of a computer, for example processor and memory, on a single integrated circuit chip.
Project log	A document to record the progress made, key activities and decisions taken during the development of a project.
Test plan	A document that provides a structured approach for testing hardware and software. It describes the purpose of the tests, any input test data, actual test results and comments/justification.

This is a key summary of the types of evidence used for BTEC International Level 3 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.
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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