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LEVEL 3  
FOUNDATION  
TECHNICAL LEVEL  
**ENGINEERING**

360 GLH (TVQ01019)

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LEVEL 3  
TECHNICAL LEVEL  
**ENGINEERING:  
MECHATRONIC  
ENGINEERING**

720 GLH (TVQ01016)

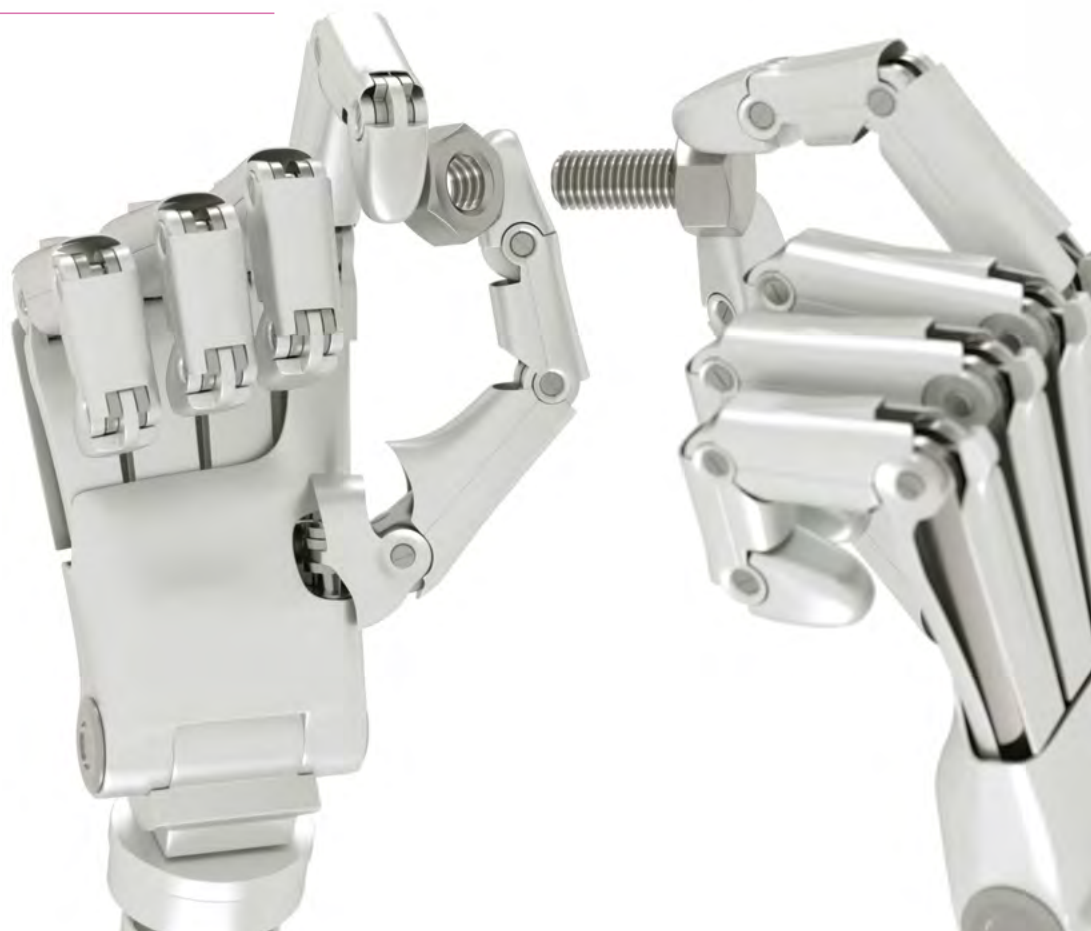
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**Specifications**

First registration September 2016 onwards

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Version 5.1 November 2018



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# 1 About these qualifications

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These qualifications are Advanced (Level 3) Technical qualifications, on a par with A-levels and have been built in close collaboration with employers and professional bodies ensuring that they have both recognition and value.

They are for learners over the age of 16 who wish to specialise or progress into a specific sector or specific occupational group, through advanced/higher apprenticeships, further study or employment.

Transferable skills (sometimes known as 'soft skills') have been contextualised explicitly within the content of each qualification. These transferable skills have been prioritised by employers and professional bodies in this sector and are a mandatory part of the qualification outcome. It is important to note that learners **must** demonstrate successful achievement of the identified transferable skill(s) appropriate to the qualification on at least **one** occasion to the required standard.

The Statements of purpose (pages 12 and 17) give more detail on the likely progression for learners with these qualifications.

Each qualification is one of the three components of the new Technical Baccalaureate (TechBacc).

The TechBacc is a performance table measure which recognises the highest level of technical training. It recognises the achievement of learners taking a Technical Level qualification, a Level 3 maths qualification and an Extended Project Qualification (EPQ).

## 2 Qualifications at a glance – overview

### 2.1 Level 3 Foundation Technical Level Engineering

Ofqual qualification number	601/7079/7	AQA qualification number	TVQ01019
First registration date	September 2016	Age range	16–18, 19+
Last registration date	31 August 2020	UCAS points	Information on UCAS points can be obtained from <a href="https://ucas.com">ucas.com</a>
Last certification date	31 August 2023	Performance table points	Information on performance measures can be obtained from <a href="https://education.gov.uk">education.gov.uk</a>
Total qualification time (TQT)	380 (GLH = 360) (See TQT section for more information)	Eligibility for funding	Yes
Unit weighting	25 % per unit	Entry requirements	There are no formal entry requirements for this qualification set by AQA.

Mandatory units	All units in this qualification are mandatory.
Resits, resubmissions and retakes	<p>The learner is permitted one resit/retake in relation to each unit of the qualification.</p> <p>Where a unit is examined/externally assessed, this means one resit. Where a unit is internally assessed and externally quality assured, this means one retake.</p> <p>Resits, resubmissions and retakes are each permitted where learners have both failed the requirements of the unit and where the learner wishes to improve on a grade received.</p> <p>Any resubmission of an assignment (ie a second attempt at an internally assessed unit task/ assignment prior to external quality assurance) must be undertaken without further guidance from the tutor and must be completed within a defined and reasonable period of time following the learner receiving their initial result of the assessment.</p>

Assessment model	This qualification contains externally examined and internally assessed units. Internally assessed units are externally quality assured by AQA.	Examination sessions	January and June each year.
Employer involvement during delivery	It is a requirement that employers are engaged meaningfully in the delivery of this qualification. Further information on this can be found in the individual units (where relevant) and the Meaningful employer involvement section.		
Grading	<p>The units are graded Pass, Merit or Distinction</p> <p>The overall qualification is graded as P, M, D, D*</p>		

### Transferable skills contextualised within the units of this qualification

These are the skills deemed essential by the employers and professional bodies AQA has collaborated with on the development of this qualification. We have contextualised units around these 'soft' skills. There may be more than one opportunity for each transferable skill to be evidenced to the required standard across the units within the qualification. It is important to note that learners **must** demonstrate successful achievement of the identified transferable skill(s) appropriate to the qualification on **one** occasion to the required standard in the identified unit(s). Evidence produced for the transferable skills will be internally assessed and externally quality assured.

- Communication (oral and written)
- Problem-solving
- Teamwork



## 2.2 Level 3 Technical Level Engineering: Mechatronic Engineering

Ofqual qualification number	601/7080/3	AQA qualification number	TVQ01016
First registration date	September 2016	Age range	16–18, 19+
Last registration date	31 August 2020	UCAS points	Information on UCAS points can be obtained from <a href="https://ucas.com">ucas.com</a>
Last certification date	31 August 2023	Performance table points	Information on performance measures can be obtained from <a href="https://education.gov.uk">education.gov.uk</a>
Total qualification time (TQT)	760 (GLH = 720) (See TQT section for more information)	Eligibility for funding	Yes
Unit weighting	12.5 % per unit	Entry requirements	There are no formal entry requirements for this qualification set by AQA.

Mandatory units	All units in this qualification are mandatory.
Resits, resubmissions and retakes	<p>The learner is permitted one resit/retake in relation to each unit of the qualification.</p> <p>Where a unit is examined/externally assessed, this means one resit. Where a unit is internally assessed and externally quality assured, this means one retake.</p> <p>Resits, resubmissions and retakes are each permitted where learners have both failed the requirements of the unit and where the learner wishes to improve on a grade received.</p> <p>Any resubmission of an assignment (ie a second attempt at an internally assessed unit task/ assignment prior to external quality assurance) must be undertaken without further guidance from the tutor and must be completed within a defined and reasonable period of time following the learner receiving their initial result of the assessment.</p>

<b>Assessment model</b>	This qualification contains externally examined and internally assessed units. Internally assessed units are externally quality assured by AQA.	<b>Examination sessions</b>	January and June each year.
<b>Employer involvement during delivery</b>	It is a requirement that employers are engaged meaningfully in the delivery of this qualification. Further information on this can be found in the individual units (where relevant) and the Meaningful employer involvement section.		
<b>Grading</b>	<p>The units are graded Pass, Merit or Distinction</p> <p>The overall qualification is graded as PP, MP, MM, DM, DD, D*D, D*D*</p>		

#### Transferable skills contextualised within the units of this qualification

These are the skills deemed essential by the employers and professional bodies AQA has collaborated with on the development of this qualification. We have contextualised units around these 'soft' skills. There may be more than one opportunity for each transferable skill to be evidenced to the required standard across the units within the qualification. It is important to note that learners **must** demonstrate successful achievement of the identified transferable skill(s) appropriate to the qualification on **one** occasion to the required standard in the identified unit(s). Evidence produced for the transferable skills will be internally assessed and externally quality assured.

- Communication (oral and written)
- Problem-solving
- Research
- Teamwork

# 3 Level 3 Foundation Technical Level Engineering: Statement of purpose

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## 3.1 Qualification objective

The objective of this qualification is:

- preparing learners to progress to a qualification in the same subject area but at a higher level or requiring more specific knowledge, skills and understanding
- meeting relevant programmes of learning
- preparing learners for employment
- giving learners personal growth and engagement in learning.

## 3.2 Who is this qualification for?

This qualification is designed for 16 to 19 year-old learners in full-time education who are interested in pursuing a career in the engineering sector and who are interested in engineering technology.

The qualification could lead to further study in engineering, or learners could proceed into an engineering-related apprenticeship or employment.

The main purpose is to allow learners to develop the core specialist knowledge, understanding and skills required by the sector.

Learners would take this qualification if they wanted an introductory qualification to develop some of the fundamental skills and knowledge required by employers in the engineering industry.

There are no formal entry requirements for this qualification, but, in order to optimise their chances of success, a learner will typically have four GCSEs at grade C or above, including Maths and English, and would benefit from having studied a science and/or related subjects such as design and technology.

The qualification is likely to be taken alongside programmes such as other Tech-levels or AS over a one or two year course of study.

This qualification could be taken alongside a Level 3 maths qualification and EPQ to fulfil the requirements of a Technical Baccalaureate.

## 3.3 What does this qualification cover?

Learners will complete four units (see Section 4) and all of the units in this qualification are mandatory. One of the units is examined and one is an externally marked practical assignment. The other two units are internally set and marked by the tutor. The industrial focus for the learning (and assessment of the internally assessed units) can be contextualised around any engineering sector or employer to suit the needs of the learners.

AQA has worked with employers and professional bodies in the design and content of this qualification to ensure that it covers all the knowledge and skills that are appropriate for a learner to gain the core underpinning knowledge, understanding and skills needed for progression into employment or further study.

The learner will cover topics such as:

- the scientific principles used by engineers to identify the most suitable materials in a given engineering context
- mechanical engineering systems and components
- the process of engineering design
- the relevance and role that manufacturing processes and systems have in the production of multiple components.

Transferable skills are those generic 'soft skills' that are valued by employers and higher education alike. The following transferable skills have been contextualised into the content of the qualification:

- communication (oral and written)
- teamwork
- problem-solving.

Units which provide opportunities to achieve these skills are listed below:

Unit code	Unit title	Transferable skill(s)
D/506/6008	Engineering design	Communication and problem-solving
H/506/6009	Production and manufacturing	Teamwork

Opportunities for each available transferable skill will be highlighted in the pass criteria for the unit where appropriate.

There may be more than one opportunity for each transferable skill to be evidenced to the required standard across the units within the qualification. It is important to note that learners **must** demonstrate successful achievement of the identified transferable skill(s) appropriate to the qualification on at least **one** occasion to the required standard.

The Transferable skills standards can be found in Appendix A.

### 3.4 What could this qualification lead to?

Learners who achieve this qualification will have a range of options, as studying this qualification does not restrict future progression into one particular route.

The qualification can be taken alongside a Level 3 maths qualification (including Core Maths) and an EPQ to fulfil the requirements of the Technical Baccalaureate performance table measure that records the achievement of students taking advanced (Level 3) programmes.

This qualification could be taken alongside complementary subjects, such as GCEs in Maths and/or Physics or other technical vocational qualifications to form part of the learner's basis for application to a higher education (HE) course (degree, foundation degree, HNC/HND) in specific related higher education courses such as Electronic Engineering, Mechanical Engineering, Mechatronic Engineering or general engineering courses.

This qualification is part of a larger suite of Level 3 AQA Technical Levels in Engineering and could form the first half of the following qualifications:

- AQA Level 3 Technical Level Engineering: Design Engineering
- AQA Level 3 Technical Level Engineering: Mechatronic Engineering.

### 3.5 Who supports this qualification?

This qualification has been developed in collaboration with employers, professional bodies and key stakeholders in the engineering sector. Because of this, the knowledge, skills and competencies gained will provide the best possible opportunity for progression into employment, a higher or advanced apprenticeship or higher education.

This qualification is supported by the following organisations:

Name	Website address
Society of Operations Engineers (SOE)	<a href="http://soe.org.uk">soe.org.uk</a>
Siemens	<a href="http://siemens.co.uk/answers/en/">siemens.co.uk/answers/en/</a>
Autodesk	<a href="http://autodesk.co.uk/">autodesk.co.uk/</a>
Festo	<a href="http://festo.com/net/startpage/">festo.com/net/startpage/</a>
Women in Science Engineering and Technology (WISET)	<a href="http://wiset.org.uk/">wiset.org.uk/</a>

### 3.6 What are the benefits of this qualification?

#### To learners

The AQA Foundation Technical Level in Engineering will allow learners the opportunity to learn and understand the core principles and technologies that underpin modern engineering. It will provide them with opportunities to develop sound practical engineering investigation, design, construction, and testing skills which are critical to being a good technician and/or incorporated engineer.

The qualification has been developed with reference to relevant National Occupational Standards to ensure it offers opportunities to demonstrate key industry relevant skills.

#### To employers

This qualification will provide the core technical knowledge required for preparing to work in the engineering industry and reflects the nature of modern engineering. This includes:

- analytical and scientific methods for engineers
- mechanical, electrical, electronic and digital principles and applications
- applications of pneumatics and hydraulics
- health, safety and risk assessment in engineering
- plant and process principles and applications.

The *Shortage Occupation List* published by the Government in April 2015 listed a number of different engineering jobs covered by the relevant SOC codes (sub-major groups 31 and 21) as suffering from a shortage of skilled workers.

*Shortage Occupation List:* [gov.uk/government/publications/tier-2-shortage-occupation-list](http://gov.uk/government/publications/tier-2-shortage-occupation-list)

This qualification is mapped to the Standard Occupational Classification (SOC) minor groups 212 (engineering professionals) and 311 (science, engineering and productions technicians) and the following related occupational groups:

- 3119 science, engineering and production technicians NEC.

Job holders in this unit group perform a variety of technical support functions not elsewhere classified in minor group 311: science, engineering and production technicians.

Tasks:

- sets up apparatus for experimental, demonstration or other purposes
- undertakes tests and takes measurements and readings
- performs calculations and records and interprets data.

- 3122 draughtspersons.

Draughtspersons prepare technical drawings, plans, maps, charts and similar items.

Tasks:

- examines design specification to determine general requirements
- considers the suitability of different materials with regard to the dimensions and weight and calculates the likely fatigue, stresses, tolerances, bonds and threads
- prepares design drawings, plans or sketches and checks feasibility of construction and compliance with safety regulations
- prepares detailed drawings, plans, charts or maps that include natural features, desired surface finish, elevations, electrical circuitry and other details as required
- arranges for completed drawings to be reproduced for use as working drawings.

## To higher education institutions (HEIs)

The qualification has been developed with the needs of higher education in mind.

Representatives from HEIs have highlighted the inclusion of examinations in the assessment as a crucial way of better preparing students for further study.

They also stated that the qualification should contain an amount of academic knowledge content that will provide a foundation for further study in engineering.

Tech-level students who completed this qualification would be able to progress onward to take courses in various fields for example:

- mechanical engineering and materials science
- electronic engineering
- design engineering
- systems and control engineering.

As part of an academic study programme, this qualification could also form part of the learner's basis for application to a higher education course in engineering, alongside complementary subjects, such as GCEs in Maths and Physics or other technical vocational qualifications.

# 4 Level 3 Foundation Technical Level Engineering: Unit summary

This qualification is made up of four mandatory units. All units must be completed to achieve the full qualification.

	Unit title	Assessment type	Ofqual unit reference
1	Materials technology and science	External examination	F/506/5952
2	Mechanical systems	Externally set and marked assignment	H/507/6524
4	Engineering design	Internally centre assessed	D/506/6008
5	Production and manufacturing	Internally centre assessed	H/506/6009

## Links with other qualifications

The following units:

F/506/5952 1 Materials technology and science

H/507/6524 2 Mechanical systems

D/506/6008 4 Engineering design

H/506/6009 5 Production and manufacturing

also appear within:

AQA Level 3 Technical Level Engineering: Mechatronic Engineering

AQA Level 3 Technical Level Engineering: Design Engineering.

# 5 Level 3 Technical Level Engineering: Mechatronic Engineering: Statement of purpose

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## 5.1 Qualification objective

The objective of this qualification is:

- meeting relevant programmes of learning
- preparing learners for employment
- supporting a role in the workplace
- giving learners personal growth and engagement in learning.

## 5.2 Who is this qualification for?

Mechatronics represents that interface between mechanical and electrical engineering and the use of programmable computers and control systems.

This qualification is aimed at 16 to 18 learners who are in full-time Level 3 education and who wish to develop the knowledge and skills that are critical to being an effective mechatronics technician and/or engineer.

There are no formal entry requirements for this qualification but in order to optimise their chances of success, a learner will typically have four GCSEs at grade C or above, including Maths, English and would benefit from having studied a science and/or computing.

This qualification could be taken alongside a Level 3 maths qualification and EPQ to fulfil the requirements of a Technical Baccalaureate.

## 5.3 What does this qualification cover?

Learners will complete eight units (see Section 6) and all of the units in this qualification are mandatory. AQA has worked with employers and professional bodies in the design and content of this qualification to ensure that it covers all the knowledge and skills that are appropriate for a learner to fully understand the interface between mechanical and electronic engineering within a modern engineering context – learning and understanding the core principles and technologies that underpin mechatronics as well as the use of programmable computers and control systems.



The learner will cover topics such as:

- the scientific principles used by engineers to identify the most suitable materials in a given engineering context
- use of maths as an aid to model and solve problems across a range of practical engineering contexts
- mechanical engineering systems and components
- the design and construction of a mechatronic control system
- the process of engineering design
- the relevance and role that manufacturing processes and systems have in the production of multiple components
- designing programs to drive engineering systems.

This qualification has been developed to reflect the content of the *National Occupational Standards for Mechatronic Systems Principles and Fault-finding* (POWPF06).

Transferable skills are those generic 'soft skills' that are valued by employers and higher education alike. The following transferable skills have been contextualised into the content of the qualification:

- communication (oral and written)
- research
- teamwork
- problem-solving.

Units which provide opportunities to achieve these skills are listed below:

Unit code	Unit title	Transferable skill(s)
D/506/6008	Engineering design	Communication and problem-solving
H/506/6009	Production and manufacturing	Teamwork
R/506/6023	Mechatronic project management	Communication and research
D/506/6025	Programming for engineers	Research

Opportunities for each available transferable skill will be highlighted in the pass criteria for the unit where appropriate.

There may be more than one opportunity for each transferable skill to be evidenced to the required standard across the units within the qualification. It is important to note that learners **must** demonstrate successful achievement of the identified transferable skill(s) appropriate to the qualification on at least **one** occasion to the required standard.

The Transferable skills standards can be found in Appendix A.

## 5.4 What could this qualification lead to?

Learners who achieve this qualification will have a range of options as studying this qualification does not restrict future progression into one particular route.

This qualification is approved by the Engineering Council as contributing to the requirements for professional registration as an engineering technician (EngTech) – see Section 5.7 for more information.

This qualification could provide entry to employment through a higher or advanced apprenticeship in the engineering sector.

Examples of potential career opportunities are aeronautical engineer, aerospace engineer, aircraft technician, automation engineer, automotive engineer, electrical/electronic engineer, electro mechanical engineer, engineering technician, instrumentation engineer, maintenance engineer, manufacturing engineer, marine engineer, mechanical engineer, mechanical technician, plant engineer, process engineer, process monitoring and plant systems engineer, project engineer, software engineer, systems engineer.

The qualification can be taken alongside a Level 3 maths qualification (including Core Maths) and an EPQ to fulfil the requirements of the Technical Baccalaureate performance table measure that records the achievement of students taking advanced (Level 3) programmes.

This qualification could also form part of the learner's basis for application to a higher education course (degree, foundation degree, HNC/HND) such as Electronic Engineering, Mechanical Engineering, Mechatronic Engineering or general engineering courses.

### Siemens Mechatronic Systems Certification Program (SMSCP)

The content and subject areas of the Siemens Mechatronic Systems Certification Program (SMSCP) and the AQA Mechatronic qualification framework are aligned and interested educational institutions can implement the SMSCP easily into the AQA Mechatronic qualification, which will be rewarded by AQA.

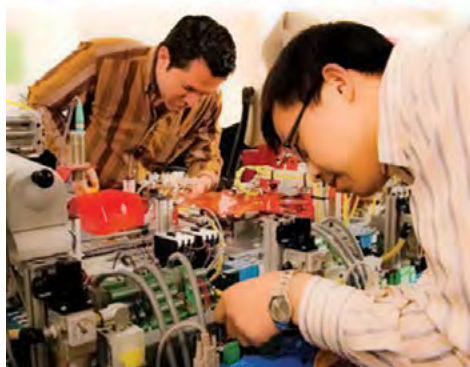
The SMSCP is **not** exclusively available together with the AQA Mechatronic qualification. Educational institutions who use other qualification frameworks can also join the SMSCP.

The Siemens Mechatronic Systems Certification Program (SMSCP) is a comprehensive industry skills certification offered together with partner schools worldwide. A central theme in the SMSCP is the System approach, a special set of teaching and learning methods developed over 25 years in Siemens technical schools in Germany.

The SMSCP was developed at the Siemens Technik Akademie Berlin and is offered in the UK in cooperation with Siemens UK.

# SIEMENS

Please visit the website for further information at  
[siemens-certifications.com/content/0/9131/9147](https://www.siemens-certifications.com/content/0/9131/9147)



## 5.5 Who supports this qualification?

This qualification has been developed in collaboration with employers, professional bodies and key stakeholders in the engineering sector. Because of this, the knowledge, skills and competencies gained will provide the best possible opportunity for progression into employment, a higher or advanced apprenticeship or higher education.

This qualification is supported by the following organisations:

Name	Website address
Engineering Council	<a href="http://engc.org.uk/">engc.org.uk/</a>
The Royal Academy of Engineering	<a href="http://raeng.org.uk">raeng.org.uk</a>
The Institution of Engineering and Technology (IET)	<a href="http://theiet.org">theiet.org</a>
Aircraft Research Association Ltd	<a href="http://ara.co.uk/">ara.co.uk/</a>
Aston University	<a href="http://aston.ac.uk/">aston.ac.uk/</a>
Automated Technology Group	<a href="http://atg.gb.com/">atg.gb.com/</a>
Birmingham City University	<a href="http://bcu.ac.uk/">bcu.ac.uk/</a>
Festo	<a href="http://festo.com/net/startpage/">festo.com/net/startpage/</a>
Liebherr	<a href="http://liebherr.co.uk">liebherr.co.uk</a>
National Forum of Engineering Centres (NFEC)	<a href="http://nfec.org.uk">nfec.org.uk</a>
Royal Mail	<a href="http://royalmail.com/">royalmail.com/</a>
Siemens	<a href="http://siemens.co.uk/answers/en/">siemens.co.uk/answers/en/</a>
Society of Operations Engineers (SOE)	<a href="http://soe.org.uk">soe.org.uk</a>
Women in Science Engineering and Technology (WISSET)	<a href="http://wiset.org.uk/">wiset.org.uk/</a>

## 5.6 What are the benefits of this qualification?

### To learners

The AQA Level 3 Technical Level Mechatronic Engineering will allow learners the opportunity to learn and understand the core principles and technologies that underpin mechatronics. It will also provide them with opportunities to develop sound practical mechatronics investigation, design, construction, testing and project skills which are critical to being an effective mechatronics technician and/or incorporated engineer.

The qualification will develop learners' ability to take a holistic 'system' approach to engineering and not see units of learning as unconnected areas of study. They will develop key industry competencies such as fault-finding, diagnosis and resolution, logic and computational thinking, and the transferability of knowledge and understanding from system areas.

The qualification also creates a route towards meeting the academic requirements for engineer technician (EngTech) status.

The qualification would provide learners with progression opportunities to take on mechatronics maintenance technicians roles. People who carry out this role ensure that engineering plant and equipment perform to the required standard to facilitate production targets regarding safety, quality, delivery and cost within high value manufacturing environments. Typically the work would cover a range of activities including installation, testing, fault-finding and the ongoing planned maintenance of complex automated equipment.

The *Shortage Occupation List* published by the Government in April 2015 listed the following jobs covered by this qualification as suffering from a shortage of skilled workers:

- 2122 mechanical engineers
- 2124 electronics engineers.

*Shortage Occupation List:* [gov.uk/government/publications/tier-2-shortage-occupation-list](http://gov.uk/government/publications/tier-2-shortage-occupation-list)

## To employers

This qualification is linked to the following Standard Occupations Classification (SOC) code to prepare learners for work in these areas:

- 2122 mechanical engineers
- 2124 electronics engineers
- 3112 electrical and electronics technicians
- 3113 engineering technicians.

### 2122 mechanical engineers

Mechanical engineers undertake research and design, direct the manufacture and manage the operation and maintenance of engines, machines, aircraft, vehicle and ships' structures, building services and other mechanical items.

### 2124 electronics engineers

Electronics engineers undertake research and design, direct construction and manage the operation and maintenance of electronic motors, communications systems, microwave systems, and other electronic equipment.

### 3112 electrical and electronics technicians

Electrical and electronics technicians perform a variety of miscellaneous technical support functions to assist with the design, development, installation, operation and maintenance of electrical and electronic systems.

### 3113 engineering technicians

Engineering technicians perform a variety of technical support functions to assist engineers with the design, development, operation, installation and maintenance of engineering systems and constructions.

The qualification has been approved and supported by the IET and employers as fit for purpose, and cover Engineering Council requirements for EngTech registration.

The qualification will embed the occupational behaviours (soft skills) that have been specified by the industry as key to preparing them for employment. They include:

- logical approach to engineering work
- problem-solving orientation
- clear communicator
- team player
- application of 'lean manufacturing principles'
- adaptability.

This qualification will provide the core technical knowledge required for preparing to work in the engineering industry and reflects the nature of modern engineering. This includes:

- analytical and scientific methods for engineers
- project design, implementation and evaluation
- instrumentation and control principles and applications
- mathematics for engineers
- mechanical, electrical, electronic and digital principles and applications
- quality assurance principles within mechatronic systems
- applications of pneumatics and hydraulics
- health, safety and risk assessment in engineering
- plant and process principles and applications
- condition monitoring and fault diagnosis.

The qualification will cover the relevant National Occupational Standard (NOS) mechatronics systems principles and fault-finding. This includes:

- the principles of the 'total engineering approach' to production systems
- applying the principles of typical sensors
- applying the principles of pneumatic, hydraulic, mechanical and electrical actuation systems
- applying the principles of embedded control
- carrying out fault-finding on pneumatic, hydraulic, mechanical and electrical actuation systems.

## To higher education institutions (HEIs)

The qualification has been developed with the needs of higher education in mind.

Representatives from HEIs have highlighted the inclusion of examinations in the assessment as a crucial way of better preparing students for further study.

They also stated that the qualification should contain a significant amount of maths and science content that will provide a foundation for further study in engineering.

HE have said that they wanted learners to come to them with an appreciation of systems engineering and that engineers need an understanding of how each branch of engineering (ie electronic and mechanical) interacts.

Mechatronic students would be able to progress onward to take courses in various fields for example:

- mechanical engineering and materials science
- electronic engineering
- computer engineering
- computer science
- systems and control engineering.

## 5.7 Links to professional body memberships

This qualification is approved by The Institution of Engineering and Technology (IET) on behalf of the Engineering Council as contributing to the requirements for professional registration as an engineering technician (EngTech). Please note that holding an approved qualification alone does not guarantee the award of the professional title EngTech. All potential registrants must undergo a professional review by their chosen Professional Engineering Institution, where their competence and commitment is assessed.

For further details about approved status, please refer to: [engc.org.uk/techdb](http://engc.org.uk/techdb)



The Engineering Council was incorporated by Royal Charter in 1981 and is the UK regulatory body for the engineering profession, holding the Register of 235,000 professional engineers and technicians.

In addition, the Engineering Council sets and maintains the internationally recognised standards of professional competence and ethics that govern the award and retention of these titles, the *UK Standard for Professional Engineering Competence* (UK-SPEC).

# 6 Level 3 Technical Level Engineering: Mechatronic Engineering: Unit summary

This qualification is made up of eight mandatory units. All units must be completed to achieve the full qualification.

	Unit title	Assessment type	Ofqual unit reference
1	Materials technology and science	External examination	F/506/5952
2	Mechanical systems	Externally set and marked assignment	H/507/6524
3	Mathematics for engineers	External examination	J/506/5953
4	Engineering design	Internally centre assessed	D/506/6008
5	Production and manufacturing	Internally centre assessed	H/506/6009
6	Mechatronic project management	Internally centre assessed	R/506/6023
7	Mechatronic control systems	Internally centre assessed	Y/506/6024
8	Programming for engineers	Internally centre assessed	D/506/6025

## Links with other qualifications

The following units:

F/506/5952 1 Materials technology and science

H/507/6524 2 Mechanical systems

J/506/5953 3 Mathematics for engineers

also appear within:

AQA Level 3 Technical Level Engineering: Design Engineering

The following units:

D/506/6008 4 Engineering design

H/506/6009 5 Production and manufacturing

also appear within:

AQA Level 3 Technical Level Engineering: Design Engineering.



# 7 Meaningful employer involvement

## 7.1 Introduction

It is important that centres develop an approach to teaching and learning that supports the assessment of the technical focus of a Tech-level qualification. The specification contains a balance of practical skills and knowledge requirements and centres need to ensure that appropriate links are made between theory and practice in a way that is relevant to the occupational sector.

This will require the development of relevant and up-to-date training materials that allow learners to apply their learning to actual events and activity within the sector, and to generate appropriate evidence for their portfolio.

It is a requirement that employers are involved in the delivery and/or assessment of the Tech-level to provide a clear 'line of sight' to work, advanced/higher apprenticeships or higher education. Employer engagement enriches learning, raises the credibility of the qualification in the eyes of employers, parents and learners – as well as also furthering the critical collaboration between the learning and skills sector, and industry.

**It is therefore a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.**

Such is the importance of meaningful employer involvement in the delivery of this qualification, should a centre be unable to evidence this, we will impose a sanction, together with an associated action plan. Further information on this process can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications*.

AQA will not stipulate the minimum duration or contribution of employer involvement to the overall qualification grade as it is important that centres and employers are allowed flexibility in how best to work together to support learning and in which units – but this collaboration must be significant.

## 7.2 Definition of meaningful employer involvement

In order to meet our requirements, meaningful employer involvement must take at least one of the following forms:

- learners undertake structured work experience or work placements that develop skills and knowledge relevant to this qualification
- learners undertake project work, exercises and/or assessments set with input from industry practitioners – such as getting employers involved in developing real life case studies, or assignments
- learners take one or more units delivered or co-delivered by an industry practitioner – this could be in the form of masterclasses or guest lectures
- industry practitioners operating as 'expert witnesses' that contribute to the assessment of a learner's work or practice, operating within a specified assessment framework. This may be for specific project work, exercises or examinations, or all assessments for a qualification.



For the purpose of clarity, the following activities, whilst valuable, would **not** be considered as meaningful employer involvement:

- employers hosting visits, providing premises, facilities or equipment
- employers or industry practitioners providing talks or contributing to delivery on employability, general careers advice, CV writing and interview training
- learner attendance at career fairs, events or other networking opportunities
- simulated or centre-based working environments
- employers providing learners with job references.

More information on employer involvement in the delivery of technical level qualifications can be found at:

*Employer Involvement in Qualifications Delivery and Assessment – Research report* (April 2014)

[gov.uk/government/uploads/system/uploads/attachment\\_data/file/306280/RR341 - Employer Involvement in Qualifications Delivery and Assessment Research Report.pdf](https://gov.uk/government/uploads/system/uploads/attachment_data/file/306280/RR341_-_Employer_Involvement_in_Qualifications_Delivery_and_Assessment_Research_Report.pdf)

Post-16 work experience as a part of 16 to 19 study programmes and traineeships – departmental advice for post-16 education and training providers:

[gov.uk/government/uploads/system/uploads/attachment\\_data/file/268624/document.pdf](https://gov.uk/government/uploads/system/uploads/attachment_data/file/268624/document.pdf)

## 7.3 Employer involvement in quality assurance

We need to make sure that the assessment remains relevant and valid, and that learning outcomes are what employers and higher education institutions are expecting of a learner who has achieved a Level 3 Tech-level qualification.

Each year a panel, including representatives from employers and HE, will be brought together to review outcomes from the units and we will ask for samples of learner work from your centre at each AQA external quality assurer (EQA) visit.

We are keen to work collaboratively with employers and HE to make sure that whatever the progression route chosen by the learner, this qualification will be recognised and valued.

If you have a local employer that would like to be involved in this review, we would be very pleased to consider them. Please email their contact details to [techlevels@aqa.org.uk](mailto:techlevels@aqa.org.uk)

## 8 Synoptic delivery and assessment

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The definition of synoptic assessment used by AQA is:

‘A form of assessment which requires a learner to demonstrate that they can identify and use effectively, in an integrated way, an appropriate selection of skills, techniques, concepts, theories, and knowledge from across the whole qualification or unit, which are relevant to a key task’.

The design of this qualification allows learners to develop knowledge, understanding and skills from some units and then evidence this learning in the performance outcomes contained within other units.

The significant amount of synoptic content within the Tech-level supports synoptic learning and assessment by:

- showing teaching and learning links between the units across the specification
- giving guidance or amplification relating to the grading criteria for the internally assessed units, about where learners could apply the knowledge and understanding from other units
- providing a coherent learning programme of related units
- allowing holistic delivery and the application of prior or concurrent learning
- providing opportunities for the learning and assessment of multiple units combined together to promote holistic delivery
- developing and assessing learners’ use of transferable skills in different contexts.

Whilst we do not prescribe in which order the units should be delivered or assessed, it is important for centres to be aware of the links between the units so that the teaching, learning and assessment can be planned accordingly. This way, when being assessed, learners can apply their learning in ways which show they are able to make connections across the qualification.

Within each unit we provide references to where the unit content maps from or to other units within the qualification. This will help the learner understand where there are explicit opportunities for synoptic learning as well as synoptic assessment.

For example, learners will be able to see very clearly how they can apply the under-pinning knowledge and theory from the core units into real life or work-related tasks – such as projects and work experience – within the specialist units.

This approach will also enable learners to integrate transferable skills much valued by employers and HE into their assignments.

**It is therefore a requirement that all learners undertake meaningful synoptic learning and assessment during their study.**

**Plans for how this will be undertaken will be scrutinised as part of our centre approval process and its implementation monitored during our ongoing quality assurance activities with centres.**

The following grids demonstrate the overall synoptic coverage in each unit of the qualification:

### Foundation Technical Level (360 GLH) in Engineering (TVQ01019)

Unit	Pass criteria	Synoptic links to other units	% of synoptic assessment
Materials technology and science	n/a	Mechanical systems Engineering design Production and manufacturing	n/a
Mechanical systems	n/a	Materials technology and science Engineering design Production and manufacturing	n/a
Engineering design	P2, P3, P5, P7, P8, P9, P10, P12 and P13	Materials technology and science Mechanical systems Production and manufacturing	9/13 pass criteria (69 %)
Production and manufacturing	P1, P2, P4, P6, P7, P8, P9, P10, P11 and P12	Materials technology and science Mechanical systems Engineering design	10/12 pass criteria (83 %)

### Technical Level (720 GLH) in Engineering: Mechatronic Engineering (TVQ01016)

Unit	Pass criteria	Synoptic links to other units	% of synoptic assessment
Materials technology and science	n/a	Mechanical systems Engineering design Production and manufacturing	n/a
Mechanical systems	n/a	Materials technology and science Mathematics for engineers Engineering design Production and manufacturing	n/a
Mathematics for engineers	n/a	Materials technology and science Mechanical systems Engineering design Production and manufacturing Mechatronic project management Mechatronic control systems Programming for engineers	n/a
Engineering design	P2, P3, P5, P7, P8, P9, P10, P12 and P13	Materials technology and science Mechanical systems Production and manufacturing	9/13 pass criteria (69 %)
Production and manufacturing	P1, P2, P4, P6, P7, P8, P9, P10, P11 and P12	Materials technology and science Mechanical systems Engineering design	10/12 pass criteria (83 %)

Unit	Pass criteria	Synoptic links to other units	% of synoptic assessment
Mechatronic project management	P3, P4, P6, P7, P8, P9, P10, P12, P13 and P14	Materials technology and science Mechanical systems Mathematics for engineers Engineering design Production and manufacturing Mechatronic control systems Programming for engineers	10/14 pass criteria (71 %)
Mechatronic control systems	P1, P2, P5, P6, P7, P8, P9, P10 and P11	Materials technology and science Mechanical systems Mathematics for engineers Engineering design Production and manufacturing Programming for engineers	8/11 pass criteria (73 %)
Programming for engineers	P2, P3, P4, P6, P9, P11, P12, P13, P14 and P15	Materials technology and science Mechanical systems Mathematics for engineers Engineering design Production and manufacturing Mechatronic control systems Programming for engineers	10/16 pass criteria (63 %)

Although the percentage of synoptic assessment for the externally assessed units is recorded as not applicable (n/a), the externally assessed units cover topics which are cross-cutting and provide learners to with an opportunity to demonstrate knowledge developed in other units.

## 9 Total qualification time

For any qualification which it makes available, Ofqual requires an awarding organisation to:

- a assign a number of hours for total qualification time to that qualification, and
- b assign a number of hours for guided learning to that qualification.

Total qualification time is the number of notional hours which represents an estimate of the total amount of time that could reasonably be expected to be required in order for a learner to achieve and demonstrate the achievement of the level of attainment necessary for the award of a qualification.

Total qualification time is comprised of the following two elements:

- a the number of hours which an awarding organisation has assigned to a qualification for guided learning (GLH)  
AQA has assigned GLH to the overall qualification and the individual units.
- b an estimate of the number of hours a learner will reasonably be likely to spend in preparation, study or any other form of participation in education or training, including assessment, which takes place as directed by – but, unlike guided learning, not under the immediate guidance or supervision of – a lecturer, supervisor, tutor or other appropriate provider of education or training.

AQA has assigned the following GLH and TQT values to its qualifications:

Qualification	Guided learning hours (GLH)	Total qualification time (TQT)
Engineering (TVQ01019)	360	380
Mechatronic Engineering (TVQ01016)	720	760

# 10 Transferable skills

These valued ‘employability’ skills are an integral and explicit element within the design and structure of all AQA Level 3 Technical Level qualifications.

Discussions and collaboration with centres, employers and stakeholders (such as further education (FE) colleges, university technical colleges (UTCs), sector skills councils, professional/trade bodies and HE), made it clear that the inclusion of these skills is regarded as a priority, and that they should be included through contextualisation within the core subject content.

Employers and stakeholders prioritised the skills they required from employees in the sector as follows:

- teamworking
- communication
- problem-solving
- research.

Rather than force the inclusion of these skills across a random selection of units or across the qualification as a whole, specific units have been identified as being most appropriate and suitable for the inclusion of a transferable skill within the subject context. The skill becomes the driver for the assessment rather than the subject content and this will be demonstrated by producing evidence to meet the required standard<sup>1</sup>. Not every unit within the qualification has a skill contextualised within the subject content.

Unit code	Unit title	Transferable skill(s)
D/506/6008	Engineering design	Communication and problem-solving
H/506/6009	Production and manufacturing	Teamwork
R/506/6023	Mechatronic project management	Communication and research
D/506/6025	Programming for engineers	Research

The skill is assessed as a performance outcome of the unit, at the Pass grade. It is assessed in the same way as any other assessment criteria within the unit.

The formal inclusion of a contextualised transferable skill does not preclude the inclusion of other ‘soft’ or ‘employability’ skills within the unit at the point of delivery, for example those which employers and HE will also value, such as critical thinking, project management, leadership, time management etc. However, these additional ‘employability’ skills will not be formally assessed as part of the unit performance outcomes.

The Transferable skills standards can be found in Appendix A.

## The AQA Skills statement

Upon the successful completion of a qualification, each learner will be issued with a Skills statement that will sit alongside their formal qualification certificate.

This Skills statement records the transferable skills that were contextualised within the units of the qualification and is an explicit way for learners to showcase the skills that have been formally assessed as part of the qualification. This Skills statement can then be used by a learner as evidence of this achievement within their CVs or HE applications.

<sup>1</sup> Please refer to Appendix A or visit the specification homepage to access the transferable skills’ standards and associated guidance and recording documentation.

# 11 Support materials and guidance

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The following delivery resources and support materials are available from AQA.

- A full Scheme of work (SOW) has been provided for each of the units in this programme.
- A sample Lesson plan has also been provided against the SOW, as a guide for good practice.
- A sample assignment for each of the internally assessed units. These are not mandated in the assessment of this qualification, but do provide a good starting point to help tutors who would benefit from assessment support.
- Sample question papers and mark schemes for the two examined units.

These are all available at [aqa.org.uk](http://aqa.org.uk)

## National STEM Centre resources

AQA have worked with the National STEM Centre, the UK's leading science, technology engineering and maths (STEM) teaching and learning resources provider, to produce a free online digital library that's designed to support you in the delivery of the two examined units that are part of our Tech-levels in engineering.

[nationalstemcentre.org.uk/aqa](http://nationalstemcentre.org.uk/aqa)

Other suggested resources can be found within the unit specification section and the schemes of work.

# 12 Qualification units

## 12.1 Unit 1: Materials technology and science

<b>Title</b>	Materials technology and science
<b>Unit number</b>	F/506/5952
<b>Unit assessment type</b>	Externally assessed
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	N/A
<b>Resources required for delivering this unit</b>	<p>Learners should have access to a range of material samples, so that they can become familiar with their properties.</p> <p>It may also be advantageous to have a range of successfully engineered products available for product analysis, to assist learners in developing their understanding of common uses of the materials.</p> <p>Learners will need access to appropriate scientific calculators and lists of the relevant formulae.</p>
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	<p>It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study.</p> <p>Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.</p> <p>This unit would logically be one of the first units taught however it could be taught after (or concurrently with) Units 2, 4 and 5, and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit. There are also opportunities to transfer learning from Unit 3 if the centre chooses to do that unit first.</p> <p>The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.</p>

### Aim and purpose

The purpose of this unit is to develop learners understanding of the materials used in engineering products and the scientific principles engineers use to identify which materials are the most suitable for use in a given engineering context.



## Unit introduction

When designing products, engineers have to select appropriate materials and components for the application. In this unit, learners will develop knowledge and understanding of a range of engineering materials and their properties. They will also consider several of the scientific principles that can affect the choice of material or components in various engineering contexts.

In particular, the learner will develop knowledge of:

- properties of materials
- engineering materials
- engineering chemistry
- electricity and electronics
- transfer of energy.

## Unit content

### Properties of materials

- The meaning of each of the following mechanical properties, their units of measurement (where applicable) and how they can be measured:
  - tensile strength
  - compressive strength
  - hardness
  - toughness
  - elasticity
  - plasticity
  - ductility
  - malleability.
- The meaning of each of the following physical properties and, where applicable, their units of measurement:
  - density
  - melting point
  - thermal conductivity
  - electrical conductivity (resistivity)
  - thermal expansion
  - corrosion resistance.
- The typical stress–strain and load–extension graphs for low carbon steel, including features such as the yield strength, ultimate tensile strength, maximum elastic deformation and maximum plastic deformation, and the calculation of stress, strain and Young’s modulus.

## Engineering materials

The source, forms of supply, typical properties, relative cost, sustainability and common applications of each of the following materials and, where appropriate, the class of material to which they belong:

- ferrous metals:
  - cast iron
  - low carbon steel (0.15–0.30 % carbon)
  - medium carbon steel (0.3–0.7 % carbon)
  - high carbon steel (0.7–1.4 % carbon)
  - stainless steel
- non-ferrous metals:
  - copper
  - aluminium and its alloys
  - titanium and its alloys
  - zinc
  - tin
  - tungsten
  - brass
- thermoplastic polymers:
  - polypropylene (PP)
  - acrylonitrile-butadiene-styrene (ABS)
  - high impact polystyrene (HIPS)
  - acrylic (PMMA)
  - polyvinyl chloride (PVC)
  - polytetrafluoroethylene (PTFE)
  - polyamide (nylon)
  - polyethylene (low and high density)
  - polycarbonates
- thermosetting polymers:
  - epoxy resin
  - polyester resin
  - urea formaldehyde
  - melamine formaldehyde
- elastomers:
  - rubber
  - neoprene
- engineering ceramics:
  - silicon carbide
  - tungsten carbide
  - borosilicate glass (Pyrex)
- composites:
  - glass reinforced plastics (GRP)
  - carbon fibre reinforced plastics (CRP)
  - reinforced concrete

## Engineering materials

- smart materials:
  - shape memory alloys (SMA)
  - quantum tunnelling composite (QTC)
  - thermochromic materials
  - photochromic materials
  - viscoelastic materials (smart grease).

## Engineering chemistry

- How cold working, crystallisation and dislocations affect the properties of metals.
- How changes of state, and phase changes, shown in equilibrium diagrams can account for the properties of alloys, such as carbon – iron and tin – lead.
- The effects of heat treatment on steels:
  - quenching
  - tempering
  - normalising
  - annealing
  - case hardening.
- The effects of precipitation hardening and annealing in aluminium alloys.
- Understanding that corrosion is a chemical process and how differing metals can be used to reduce the effects of corrosion.
- The basic chemistry of polymer materials: how monomers of alkane structures (such as methane, ethane, butane and pentane) can be used to form common polymers.
- How and why crosslinking within polymers affects the properties, manufacture and application of the material.

## Electricity and electronics

- Using mathematical methods to calculate values in electronic circuits, including:
  - current and voltage, using Ohm's law
  - resistance and capacitance, where components are in series and parallel
  - electrical power.
- The differences between analogue and digital signals.
- The characteristics and applications of magnetic fields and electromagnetic induction.
- The junction characteristics of semiconductor devices such as diodes and transistors.
- The characteristics of sinusoidal wave forms, including frequency, amplitude and periodic time.

## Transfer of energy

- Heat flow across material boundaries, including conduction, convection and radiation, and the application of these in engineering contexts.
- The operation of heat pumps involving latent heat of fusion and vaporisation.
- Kinetic energy, potential energy, gravitational force and the principle of the conservation of energy in the context of engineering (for example, simple machines such as hoists, or falling objects).
- The reasons for using pneumatic or hydraulic control systems in common engineering applications.
- The gas laws (including Boyle's law and the ideal gas law) and how these are applied in engineering.
- The characteristics of 2D fluid flow over common objects, identifying laminar flow, stagnation points, separation points, turbulence and vortices.
- Power transmission systems and simple machines, such as gear trains and belt drives. This includes using mathematical methods to calculate, or take account of, gear ratio, torque, friction and efficiency of transmission systems.

## Assessment outcomes

Learners will be able to:

### Assessment outcome 1: Understand the properties of materials

a	The mechanical properties of materials, state their units and describe how they can be measured.
b	The physical properties of materials and state their units.
c	The important mechanical and physical properties that are required in a given application.
d	The features of typical stress-strain and load-extension graphs for low carbon steel, including the yield strength, ultimate tensile strength, maximum elastic deformation and maximum plastic deformation, and calculate the stress, strain and Young's modulus.

### Assessment outcome 2: Understand engineering materials

a	The source, forms of supply, and the class of material to which a material belongs.
b	The typical properties, relative costs, sustainability and common applications of the materials stated.
c	Identifying appropriate materials for a given application and justifying their selection.

### Assessment outcome 3: Understand engineering chemistry

a	How cold working, crystallisation and dislocations affect the properties of metals.
b	How changes of state and phase changes shown in equilibrium diagrams can account for the properties of alloys.
c	The heat treatment processes used on steels and explain how they influence the properties of the steel.
d	The effects of precipitation hardening and annealing in aluminium alloys.
e	The process of corrosion and how differing metals can be used to reduce its effects.
f	How monomers of alkane can be used to form common polymers.
g	How and why crosslinking within polymers affects the properties, manufacture and application of the material.

**Assessment outcome 4: Understand electricity and electronics**

a	Use mathematical methods to calculate values in electronic circuits, including: <ul style="list-style-type: none"> <li>• current and voltage, using Ohm's law</li> <li>• resistance and capacitance, where components are in series and parallel</li> <li>• electrical power.</li> </ul>
b	The differences between analogue and digital signals.
c	The characteristics and applications of magnetic fields and electromagnetic induction.
d	The junction characteristics of semiconductor devices such as diodes and transistors.
e	The characteristics of sinusoidal waveforms, including frequency, amplitude and periodic time, using mathematical methods and graphs.

**Assessment outcome 5: Understand the transfer of energy**

a	The mechanisms for heat flow across material boundaries, including conduction, convection and radiation, and identify applications of these in engineering contexts.
b	The operation of heat pumps including the mechanism of thermal energy transfer.
c	Kinetic energy, potential energy, gravitational force and the principal of the conservation of energy in the context of engineering. Use mathematical methods to apply these in practical engineering contexts.
d	The advantages and disadvantages of using pneumatic, hydraulic and electronic control systems in common engineering applications.
e	Carry out calculations using the gas laws in engineering contexts.
f	The characteristics of 2D fluid flow over common objects, identifying laminar flow, stagnation points, separation points, turbulence and vortices.
g	Power transmission systems and simple machines, such as gear trains and belt drives, and using mathematical methods to calculate the gear ratio, torque, friction and efficiency of transmission systems.

## Assessment

This unit is assessed by an external examination set and marked by AQA. The examination takes place under controlled examination conditions and the exam date will be published at the start of each academic year.

Learners are allowed to use a non-programmable scientific calculator in the examination. Please note that in line with typical practice within the engineering industry, learners are not expected to be able to recall formulae for use when answering questions that require mathematical calculations. They are expected to be able to select, manipulate (if required) and apply appropriate equations from provided formulae sheets.

The examination consists of a written paper with two sections, A and B. Learners will have to complete both sections and there will be no optional questions within either section.

The examination is 1 hour 45 minutes duration and the total number of marks available in the examination is 80.

Section A is worth 50 marks and consist of relatively short questions based on the whole of the specification for this unit. The learners will be required to answer all of the questions in Section A.

Section B is worth 30 marks and includes both short and longer answer questions worth up to 10 marks each. Each of these focus on a practical engineering context. The questions in Section B do not necessarily cover the whole of the specification for this unit at each assessment. Learners are required to answer all of the questions in Section B.

AQA will ensure that the full content of the unit is covered equally over the life of the qualification.

## Synoptic assessment

This is an externally assessed unit. Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.

The amplification below identifies where the centre could consider synoptic learning and where learning from other units can be used to support the production of evidence for this unit.

This unit would logically be one of the first units taught however it could be taught after (or concurrently with) Units 2, 4 and 5, and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit. There are also opportunities to transfer learning from Unit 3 if the centre chooses to do that unit first.

## A01 Properties of materials

When considering the properties of materials, this could be taught concurrently with the terminology and understanding of materials selection used in Unit 2 Mechanical systems PO2.

The analysis of stress-strain and load-extension graphs to calculate material could be taught concurrently with Unit 3 Mathematics for engineers AO1 and AO6.

## A02 Engineering materials

When considering the properties of materials and types of engineering materials, learners should apply the terminology and understanding of materials selection used in Unit 2 Mechanical systems PO2 and Unit 4 Engineering design PO3 M5, and the relationship between process selection and material type in Unit 5 Production and manufacturing PO1 P1, M1 and D1.

## A03 Engineering chemistry

The interpretation and application of equilibrium diagrams could be taught concurrently with Unit 3 Mathematics for engineers AO1 and AO6.

## A04 Electricity and electronics

For electrical drives, the principles underlying their use, including both magnetic fields and waveforms, could be taught concurrently with their operating characteristics in Unit 2 Mechanical systems PO2.

When learning how to calculate values in electronic circuits, this could be taught concurrently with Unit 3 Mathematics for engineers AO1, AO2 and AO3.

## A05 Transfer of energy

When learning about the gas laws, this could be taught concurrently with Unit 3 Mathematics for engineers AO1 and AO3.

The calculation of heat flows during the operation of heat pumps and calculation of changes in energy in engineering examples could be taught concurrently with Unit 3 Mathematics for engineers AO1 and AO3.

Energy transfer in power transmission systems could be taught concurrently with the use, operation and performance of these systems in Unit 2 Mechanical systems PO1 and PO2 and Unit 3 Mathematics for engineers AO1 and AO3.

## Delivery guidance

The delivery of the scientific content within this unit should be rooted within a range of practical engineering contexts. Examining the way in which materials and components are used in real products will make a substantial contribution to learners' understanding.

Some of this unit could be planned in the context of the learning activities and themes within the other units of this qualification, or when visiting engineering companies such as heat treatment facilities, or the use of industrial contacts and designers to provide visiting lectures. By using such examples, learners will be able to relate the content to real engineering.

This unit content builds on prior learning in mathematics based on the National Curriculum requirements. It assumes that learners are able to:

- carry out basic arithmetic (add, subtract, multiply, divide, squares and square roots)
- insert values into formula and calculate answers
- use decimal notation
- use percentages
- divide a quantity in a given ratio
- use calculators effectively and efficiently.

## Essential resources

Learners should have access to a range of material samples, so that they can become familiar with their properties.

It may also be advantageous to have a range of successfully engineered products available for product analysis, to assist learners in developing their understanding of common uses of the materials.

Learners will need access to appropriate scientific calculators and lists of the relevant formulae.

## Employer engagement guidance

One method to develop employer engagement within this unit is to use visits to engineering companies. This could be in combination with activities for other units within this qualification. For example, if a visit is planned to an engineering company to look at processing techniques and methods of quality control, the learners could also consider the materials that are being used and the possible alternatives.

## Useful links and resources

At the time of publication, there are no textbooks which fully cover the specific topics in this unit. However, some relevant content can be found in the following:

- Chapman C and Finney M, *Real-World Technology – Resistant Materials*, ISBN-10: 0007115326, Collins Educational, 2nd edition (20 May 2002)
- Norman E, Cubitt J, Urry S and Whittaker M, *Advanced Design and Technology*, ISBN-10: 0582328314, Longman, 3rd edition (28 Sep 2000).

Learners may also benefit from the use of a book of standard formulae, such as:

- Greer A and Hancox D, *Tables, Data and Formulae for Engineers and Mathematicians*, ASIN: B00EKYO5P8, Nelson Thornes, 2nd edition (1988).

## National STEM Centre resources

We've worked with the National STEM Centre, the UK's leading science, technology engineering and maths (STEM) teaching and learning resources provider, to produce a free online digital library that's designed to support you in the delivery of examined units that are part of our Tech-levels in engineering.

[nationalstemcentre.org.uk/aqa](http://nationalstemcentre.org.uk/aqa)



## 12.2 Unit 2: Mechanical systems

<b>Title</b>	Mechanical systems
<b>Unit number</b>	H/507/6524
<b>Unit assessment type</b>	Centre assessed and externally quality assured
<b>Recommended assessment method</b>	<p>Practical assignment</p> <p>This is the preferred assessment method for this unit. A centre may choose an alternative method of assessment, but will be asked to justify this as part of the quality assurance process.</p>
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	N/A
<b>Resources required for delivering this unit</b>	<p>Learners should have access to a range of products that include mechanical systems for product analysis. Ideally they should have the opportunity to disassemble these products to analyse their function and the components used.</p> <p>For the designing, learners will need access to appropriate CAD and modelling software.</p> <p>For the assembly and testing, learners should have access to a wide variety of pre-manufactured or bought-in components, to enable them to select appropriate components as required. They should also have access to a range of appropriate assembly tools and test equipment, so that they can become familiar with their safe operation.</p>
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	<p>It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study. Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.</p> <p>This unit would logically be one of the first units taught after Unit 1 however it could be taught after (or concurrently with) Units 4 and 5, and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit. The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.</p>

### Aim and purpose

The purpose of this unit is to give learners a practical understanding of mechanical systems. This includes different types of mechanical systems and their typical applications, how these systems are designed, and how they and their component parts function.

## Unit introduction

Mechanical systems are used to carry out tasks that involve forces and movement. They typically involve some form of power source that generates force and movement, functional elements that change the magnitude or direction of this force or movement, a means of transmitting this force or movement to where it is required and some form of control system.

In this unit learners will explore different types of mechanical systems and their typical applications, how these systems are designed, and how they (and their component parts) function. They will also assemble and test mechanical systems and identify the preventative maintenance requirements.

## Unit content

### Types of mechanical systems and their purposes

Purpose of mechanical systems	<ul style="list-style-type: none"> <li>• Understanding the design requirements for a mechanical system.</li> <li>• Producing a specification for a mechanical system.</li> <li>• Methods of assessing the performance of a mechanical system.</li> <li>• Types of motion:               <ul style="list-style-type: none"> <li>• rotary</li> <li>• oscillating</li> <li>• linear</li> <li>• reciprocating.</li> </ul> </li> <li>• Methods of transmitting movement or force between different types of motion:               <ul style="list-style-type: none"> <li>• rotary to rotary</li> <li>• rotary to linear</li> <li>• linear to rotary</li> <li>• rotary to reciprocating</li> <li>• reciprocating to rotary</li> <li>• rotary to oscillating</li> <li>• oscillating to rotary.</li> </ul> </li> <li>• Methods of transmitting movement or force between different locations.</li> <li>• Methods of changing the direction of transmitted movement or force.</li> <li>• The use of mechanical advantage to amplify (or reduce) the movement or force of the input.</li> </ul>
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### Types of mechanical systems and their purposes

Types of mechanical system, their capabilities, limitations and typical applications

- Levers and linkage mechanisms:
  - simple slider-crank
  - four-bar linkage
  - quick return mechanisms.
- Gears and gear drives:
  - simple and compound gear trains
  - types of gear, such as spur, helical, bevel and worm gears
  - rack and pinion
  - epicyclic gears.
- Cams and followers:
  - pear, eccentric, snail/drop, swash plate, flat plate/linear and cylindrical/barrel cams
  - flat, point/knife, roller and offset followers.
- Chain and belt drives, including vee- and flat belts.
- Clutches and brakes, including dog, flat plate, and electromagnetic clutches and fluid couplings.
- Transmission shafts, including flanged, splined, flexible and constant velocity couplings.

### Designing a mechanical system

Mechanical components

- The function and application of mechanical components:
  - gears
  - shafts
  - bearings
  - seals
  - permanent fasteners
  - temporary fasteners
  - springs
  - cams
  - followers
  - casings.
- Physical properties of mechanical components
  - materials
  - lubrication requirements
  - surface properties
  - materials for gears – metals, polymers and composites.

Electrical drives

- Operating characteristics of electrical drives:
  - linear drives
  - servo motors
  - stepper motors
  - dc motors
  - ac motors.
- Factors affecting the choice of an electrical drive for an application.

### Designing a mechanical system

Design of mechanical systems	<ul style="list-style-type: none"> <li>• Drawing conventions to represent mechanical components.</li> <li>• Modelling the performance of mechanical systems using computer software.</li> </ul>
Design considerations	<ul style="list-style-type: none"> <li>• Commercial and economic context of engineering systems and processes.</li> <li>• Application considerations:               <ul style="list-style-type: none"> <li>• function</li> <li>• sustainability</li> <li>• cost</li> <li>• precision</li> <li>• safety.</li> </ul> </li> <li>• Appropriate codes of practice, legislative, statutory, technical, industry standards and safety precautions that apply when working with mechanical systems.</li> </ul>

### Assembly and operation of mechanical systems

Assembly of mechanical systems	<ul style="list-style-type: none"> <li>• Interpret and follow engineering drawings and related specifications.</li> <li>• Correct selection and safe use of appropriate materials, equipment, tools, processes, or products.</li> <li>• Methods of assembling mechanical components:               <ul style="list-style-type: none"> <li>• aligning</li> <li>• bending</li> <li>• fixing</li> <li>• mechanical jointing</li> <li>• precision measuring</li> <li>• pre-tensioning</li> <li>• sealing</li> <li>• sequential tightening</li> <li>• threaded jointing and locking devices</li> <li>• applying torque.</li> </ul> </li> <li>• Selection and implementation of appropriate quality processes.</li> </ul>
Apply safety rules while working in the workshop	<ul style="list-style-type: none"> <li>• Safety precautions:               <ul style="list-style-type: none"> <li>• risk assessment</li> <li>• safe assembly and testing of systems and devices</li> <li>• control of substances hazardous to health (COSHH).</li> </ul> </li> <li>• Use of personal protective equipment (PPE).</li> <li>• Complying with health and safety and other relevant legislation, regulations, guidelines and local rules or procedures.</li> </ul>
Testing	<ul style="list-style-type: none"> <li>• Use of appropriate test equipment.</li> <li>• Recording of test data.</li> <li>• Comparing test results with system specification.</li> <li>• Fault-finding techniques.</li> <li>• Adjusting the performance of a mechanical system.</li> </ul>

### Assembly and operation of mechanical systems

Identifying maintenance requirements	<ul style="list-style-type: none"> <li>• Preventative and routine maintenance requirements for mechanical systems.</li> <li>• Purpose and use of lubricants and lubrication systems.</li> <li>• Condition monitoring.</li> </ul>
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## Performance outcomes

On successful completion of this unit learners will be able to:

Performance outcome 1:	Understand the types of mechanical systems and their purposes.
Performance outcome 2:	Design a mechanical system.
Performance outcome 3:	Assemble and test a mechanical system.

## Grading criteria

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO1</b> <b>Understand the types of mechanical systems and their purposes</b>	<b>P1</b> Describe four different examples of mechanical systems, each of which transmits motion or force between different forms of motion.	<b>M1</b> For two different examples of mechanical systems, explain how the system changes the magnitude of the force or movement of the input.	<b>D1</b> For a mechanical system, justify the choice of mechanical systems used in the design, in terms of their operational capability.
<b>PO2</b> <b>Design a mechanical system</b>	<b>P2</b> For a given design specification, design a mechanical system to meet the desired outcomes.	<b>M2</b> Explain the way in which the mechanical components within your mechanical system operate to provide the required outcome.	
	<b>P3</b> Outline all design considerations.	<b>M3</b> Identify those that are relevant to the design.	
	<b>P4</b> Specify the components to be used in the mechanical system in order to meet a specified performance.	<b>M4</b> Explain why the chosen mechanical components are suitable for the application.	<b>D2</b> Justify the choice of three of the chosen components and identify possible alternatives.

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P5</b> Select an appropriate electric motor to power the mechanical system.	<b>M5</b> Justify the choice of electric motor for the assembled mechanical system.	
	<b>P6</b> Produce a general assembly diagram of your design, showing the mechanical components.		
<b>PO3 Assemble and test a mechanical system</b>	<b>P7</b> Produce a production plan for your product that provides the correct sequence of operations and use of tools.		
	<b>P8</b> Provide a risk assessment for the assembly process, identifying hazards, risks and control measures.		
	<b>P9</b> Carry out assembly operations to the appropriate standards and tolerances, including the correct use of relevant materials, equipment, tools, or products.	<b>M6</b> Suggest improvements or modifications that could be made to the mechanical system you have constructed.	
	<b>P10</b> Work safely at all times, complying with health and safety and other relevant legislation, regulations, guidelines and local rules or procedures.		

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P11</b> Select and use appropriate measurement methods to test the mechanical elements of the constructed system and record the results of the test in an appropriate format.	<b>M7</b> Justify the use of the selected measurement methods.	<b>D3</b> Evaluate the mechanical system you have constructed, covering how well the system meets the given specification and how testing supported any improvements made.
	<b>P12</b> Create a preventative maintenance schedule for a mechanical system.		

## Assessment

This unit is assessed by an AQA set and marked assignment. The assignment takes 20 of the 90 guided learning hours available for this unit.

The centre needs to ensure that a variety of appropriate physical resources are available for learners to use in this section. Learners are not expected to manufacture components within the assessment. They should have access to a wide variety of pre-manufactured or bought-in components, including:

- electrical drives
- components that transmit motion or power, for example shafts, gears or belts
- components that can change between different types of motion, for examples gears and linkages
- components that can change the magnitude of the input motion or force
- seals, casings, bearings, fasteners etc.

The evidence submitted for assessment should include:

- a research report or product analysis
- a general arrangement drawing of the designed item
- a materials list
- risk assessments for the manufacturing processes
- a practical diary, including annotated pictures of the assembly operation and the final products
- a quality test record sheet
- a witness statement covering safe working
- a preventative maintenance schedule for the finished product.

## Assessment amplification

**This section provides amplification of what is specifically required or exemplification of the responses learners are expected to provide.**

### P01 Mechanical systems and their purposes

To achieve **P1** the four examples to be described by learners should each convert their input motion into a different form of motion at the output (eg rotary to oscillating, linear to rotary etc). A variety of different examples should be used. For example, these could be the power transmission system in a vehicle, an automatic door opener, an electric can opener, a robot arm etc.

To achieve **M1** learners should include within their explanation a calculation of the change in magnitude of the motion (for example, the revolutions per minute) or force (for example, the mechanical advantage).

To achieve **D1** the justification should refer to the type of mechanical system used in comparison to the alternative options.

### P02 Designing mechanical systems

To achieve **P2** the design could be in the form of an annotated sketch, a scale model or a virtual model. Learners will need to be provided with an appropriate design specification. This should include functional needs (for example accuracy, repeatability and safety considerations), constraints (for example, the resources or cost) and sustainability issues.

To achieve **M2** the explanation should refer to how individual elements within the system combine together to fulfil the requirements. For example, this could refer to individual gears, bearings, and shafts. This could be achieved by a written statement or annotations on the design.

To achieve **P3** learners could annotate the design specification or add an extra column explaining why each need is important.

To achieve **P4** learners could provide a list of the materials to use. This could be a separate listing or a table on the general assembly drawing.

To achieve **M3** this could be completed as a 'reasons why' column in the list of materials. This could, for example, refer to the different types of materials available, alternative sizes, or alternative component types.

To achieve **D2** there must be three different types of component. At least two of the three components discussed should be directly involved with the transmission of motion or power, for example gears or shafts. The other component could be a seal, casing, or fastener etc. The justification could be in terms of, for example, relative performance, effect on function, economics or sustainability.

To achieve **P5** the drive source selected could be listed in the materials list or on the general assembly drawing.

To achieve **M4** the justification could be in terms of, for example, relative performance, accuracy of control, economics or sustainability.

To achieve **P6** the general assembly drawing could be produced by hand or using CAD software.

### P03 Assembly and operation of mechanical systems

To achieve **P7** learners should produce a production plan that identifies the main activities of the manufacturing process, such as, for example, the correct sequence of steps for assembling the product with materials and tools needed to be used at each stage.



To achieve **P8** the risk assessment should identify hazards, risks and control measures.

To achieve **P9** and **P10** learners could provide evidence in the form of annotated photographs or a witness statement.

To achieve **M5** learners could annotate a picture of their assembled system.

To achieve **P11** learners should produce a completed test record sheet, identifying the tests or measurement carried out, the equipment and devices used, and the outcome of the test.

To achieve **M6** learners could add the justification as an additional column if the test record form is in the tabular format.

To achieve **D3** the evaluation should be objective where practicable, based on the test results. At least two improvements should be listed and explained in terms of how they impacted, or could impact, the testing carried out.

To achieve **P12** the preventative maintenance schedule should list any lubrication requirements and their frequency, along with any condition or performance monitoring that should be carried out and the associated criteria that would trigger remedial action.

## Synoptic assessment

This is an externally assessed unit. Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.

The amplification below identifies where the centre could consider synoptic learning and where learning from other units can be used to support the production of evidence for this unit.

This unit would logically be one of the first units taught after Unit 1 however it could be taught after (or concurrently with) Units 4 and 5, and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.

## P01 Mechanical systems and their purposes

When demonstrating an understanding of design requirements and how to produce a specification, learners should apply learning from the design activities in Unit 4 Engineering design PO1.

When calculating mechanical advantage, learners should apply learning from mathematical methods of addressing practical engineering problems in Unit 3 Mathematics for engineers AO1.

## P02 Designing a mechanical system

When selecting engineering components and materials based on their properties, learners should apply the terminology, learning and understanding in Unit 1 Materials science and technology AO1 and AO2, and the understanding of how materials and components are selected for an application in Unit 4 Engineering design PO3 M5.

When learning about the application of electrical drives, learners should apply learning from Unit 1 Materials science and technology AO4, including both magnetic fields and waveforms. In addition, the factors affecting the selection of an electrical drive provide a technically-specific example that supports the more extensive design considerations in Unit 4 Engineering design PO1, PO2 and PO3.

When learning the drawing conventions to represent mechanical components, learners should apply knowledge of orthographic drawings from Unit 4 Engineering design PO2 and PO3.

### P03 Assembly and operation of mechanical systems

When interpreting and using engineering drawings, learners should apply knowledge from the use of orthographic drawings in Unit 4 Engineering design PO2 and PO3.

When performing manufacturing operations, learners should apply knowledge and skills developed in Unit 5 Production and manufacturing PO5 P11, P12, M7 and D4.

When using different methods to assemble components, learners should apply skills developed in Unit 5 Production and manufacturing PO1 and PO5. When planning assembly operations, learners should apply their knowledge and understanding from Unit 5 Production and manufacturing PO4.

When selecting and implementing quality processes, such as statistical process control, learners should apply their understanding of graphical methods, statistics and their interpretation from Unit 3 Mathematics for engineers AO1, AO5 and AO6.

When considering risk assessment and the implementation of safety rules in the workshop, learners should apply knowledge and learning developed in Unit 5 Production and manufacturing AO4 and AO5 respectively. Similarly, when demonstrating knowledge of relevant rules, regulations and legislation learners should apply knowledge and learning developed from their consideration during design in Unit 4 Engineering design PO2 P5.

Testing and the use of appropriate test equipment should apply knowledge and skills developed in the more extensive but generalised Unit 5 Production and manufacturing PO3 P5, P6, P7 and M5. Similarly, the evaluation of the design should allow learners to apply understanding and learning developed in Unit 4 Engineering design PO2. Quantification of system performance in D3 should apply the learners understanding of energy transfer in power transmission systems from Unit 1 Materials technology and Science AO5.

The practical nature of the maintenance requirements should build on learning developed about maintenance considerations during design in Unit 4 Engineering design PO1. Where this is based on graphical processes such as condition monitoring, this should apply understanding and mathematical skills developed in Unit 3 Mathematics for engineers AO1, AO5 and AO6. The documentation requirements should allow learners to apply knowledge and learning developed with Unit 4 Engineering design PO4.

### Delivery guidance

The performance outcomes should be, wherever possible, delivered through practical activities. These could include the inspection, dismantling, analysis and assembly of mechanical control systems and their components. It is important that the learner be exposed to a variety of different types of mechanical systems so that they may see the relevance of each type of system as it is being discussed.

The performance outcomes may be taken in any order. PO3 could be delivered before PO2 if it is felt that a particular group of learners would develop greater understanding of the design through carrying out the practical assembly activities first.

**Performance outcome 1** is an overview of the purpose of mechanical systems, ie transmitting movement or force between different types of motion. This should include examples of a wide range of different applications, classified according to the type of mechanical systems used.

**Performance outcome 2** develops an understanding of the components used in mechanical systems and how mechanical systems are designed. It is expected that the learners will be able to identify and use a wide range of mechanical components. Some knowledge may come from product disassembly activities, however to cover the full variety of different component types it may be advantageous to create and use a handling collection to support teaching and learning.

**Performance outcome 2** asks learners to design a pneumatic system. Centres can use a different type of fluid power system, focusing on hydraulic systems, if they prefer to.

**Performance outcome 3** involves assembling and testing mechanical systems. A range of different systems should be assembled, to allow the different assembly techniques and skills to be experienced. When presented with the design of a mechanical system, learners should also be able to plan the assembly process and ensure that any risks to health and safety are minimised.

## Essential resources

Learners should have access to a range of products that include mechanical systems for product analysis. Ideally they should have the opportunity to disassemble these products to analyse their function and the components used.

For the designing, learners will need access to appropriate CAD and modelling software.

For the assembly and testing, learners should have access to a wide variety of pre-manufactured or bought-in components, to enable them to select appropriate components as required. They should also have access to a range of appropriate assembly tools and test equipment, so that they can become familiar with their safe operation.

## Employer engagement guidance

Employer engagement within this unit could be developed through visits to engineering companies to look at the manufacture of different mechanical systems. It could also be supported through inviting specialist personnel to visit the centre as guest speakers, giving talks on the design and function of mechanical products manufactured by their company. They can also be a valuable resource for sample mechanical systems, both working and damaged, each of which can be used for training purposes.

Additionally, the brief for the manufactured product could be developed in conjunction with a local employer, for example designing and manufacturing a prototype for a potential new product.

## Useful links and resources

At the time of publication, there are no textbooks which fully cover the specific topics in this unit. However, some relevant content can be found in the following:

- Norman E, Cubitt J, Urry S and Whittaker M, *Advanced Design and Technology*, ISBN-10: 0582328314, Longman, 3rd edition (28 Sep 2000).

Useful educational websites which can provide a general introduction to mechanisms and gear systems are:

- [en.wikipedia.org/wiki/Mechanical\\_system](https://en.wikipedia.org/wiki/Mechanical_system)
- [bbc.co.uk/schools/gcsebitesize/design/systemscontrol/mechanismsrev1.shtml](http://bbc.co.uk/schools/gcsebitesize/design/systemscontrol/mechanismsrev1.shtml)
- [technologystudent.com/gears1/geardex1.htm](http://technologystudent.com/gears1/geardex1.htm)
- [technologystudent.com/cams/camdex.htm](http://technologystudent.com/cams/camdex.htm)

## 12.3 Unit 3: Mathematics for engineers

<b>Title</b>	Mathematics for engineers
<b>Unit number</b>	J/506/5953
<b>Unit assessment type</b>	Externally assessed
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	N/A
<b>Resources required for delivering this unit</b>	Learners will need access to appropriate scientific calculators and lists of the relevant formulae.
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	<p>It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study. Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.</p> <p>This unit would logically be one of the last units taught and assessed, and there are opportunities for learners to use synoptic knowledge and learning from the other units on the qualification in their evidence for this unit. The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.</p>

### Aim and purpose

The purpose of this unit is for learners to model and solve engineering problems across a range of practical engineering contexts through the use of mathematics.

### Unit introduction

When designing engineered products, or solving engineering problems, engineers frequently have to select and apply mathematical techniques and methods. In this unit, learners will develop knowledge, skills and understanding of a range of standard mathematical techniques, enabling their selection and use in practical engineering situations. In particular, the learner will develop the ability to:

- solve problems using the practical application of mathematics
- use arithmetic to solve engineering problems
- use algebra to solve engineering problems
- use trigonometry and coordinate geometry to solve engineering problems
- use statistics to solve engineering problems
- use calculus to solve engineering problems.

## Unit content

### Solving problems using the practical application of mathematics

- Apply mathematical skills to resolve engineering problems:
  - correctly determine the solution to engineering problems
  - use standard mathematical symbols, layouts and annotation
  - select appropriate information from resources (such as data tables and formulae) to be able to evaluate engineering solutions.
- Selection and application of standard mathematical techniques and methods to address real-world engineering problems.
- Methods of communicating mathematical information, including formulas, tables and graphs.
- Analysis of mathematical data.

### Using arithmetic to solve engineering problems

- Perimeter and area of 2D shapes.
- Volume of 3D shapes.
- Common measures.

### Using algebra to solve engineering problems

- Use of equations to solve engineering problems.
- Manipulation of equations to change the subject.
- Simplification of equations and functions.
- Indices.
- Quadratic equations.
- Simultaneous linear equations.
- Partial fractions.
- Interpret changes in engineering systems from graphs.
- Expressing equations of a straight line, trigonometrical and exponential functions using graphs.
- Rules of indices and laws of logarithms, including changing the base.

### Using trigonometry and co-ordinate geometry to solve engineering problems

- Mathematical and graphical methods to find the position of objects and to determine how they move relative to each other, including:
  - vector addition and subtraction
  - convert between cartesian (x, y) and polar ( $r, \theta$ ) coordinates
  - use and convert angles in both degrees and radians.
- Solution of triangles, including the sine and cosine rules.

### Using statistics to solve engineering problems

- Mean, median and modal averages.
- Cumulative frequency, variance and standard deviation.
- The use of statistical data in engineering and quality systems.

**Using calculus to solve engineering problems**

- Use graphs to find the solution to engineering problems.
- Use graphs to represent variables in engineering systems.
- Use differentiation and integration to determine the rate of change in engineering systems and to identify turning points, maximum, minimum and optimum values.

**Assessment outcomes**

Learners will be able to:

**Assessment outcome 1: Solve problems using the practical application of mathematics**

- |   |  |
|---|--|
| a | Apply mathematical skills to analyse, resolve and communicate the solutions to engineering problems.                 |
| b | Select and apply mathematical techniques and methods in real-world engineering contexts.                             |
| c | Reason mathematically, make deductions and inferences and draw conclusions.  |
| d | Interpret and communicate mathematical information in a variety of forms appropriate to the information and context. |

**Assessment outcome 2: Use arithmetic to solve engineering problems**

- |   |   |
|---|---|
| a | Calculate the perimeter and area of 2D shapes.  |
| b | Calculate the volume of 3D shapes.  |
| c | Solve practical problems requiring calculation with common measures (eg money, time, length, mass, weight, force, energy, capacity and temperature). This may include, for example, calculating or costing material requirements. |

**Assessment outcome 3: Use algebra to solve engineering problems**

- |   |  |
|---|--|
| a | Use equations to solve engineering problems. For example, in electrical systems, this could include calculating resistance (in series and parallel arrangements), voltage, current or power; and in materials, this could include the calculation of stress, strain and Young's modulus. |
| b | Manipulate equations to change the subject.  |
| c | Simplify equations and functions.  |
| d | Add and subtract indices.  |
| e | Solve quadratic equations.   |
| f | Resolve simultaneous linear equations.   |
| g | Decompose partial fractions.   |
| h | Interpret changes in engineering systems from graphs.  |
| i | Use graphs to express equations of a straight line, trigonometrical and exponential functions.   |
| j | Use rules of indices and laws of logarithms, including changing the base.  |

**Assessment outcome 4: Use trigonometry and co-ordinate geometry to solve engineering problems**

- |   |   |
|---|---|
| a | Use mathematical and graphical methods to find the position of objects, and to determine how they move relative to each other, including: <ul style="list-style-type: none"> <li>• vector addition and subtraction</li> <li>• convert between cartesian (x, y) and polar (<math>r, \theta</math>) coordinates</li> <li>• use and convert angles in both degrees and radians.</li> </ul> |
| b | Calculate the dimensions and angles of triangles, including use of the sine and cosine rules.   |

**Assessment outcome 5: Use statistics to solve engineering problems**

- |   |   |
|---|---|
| a | Calculate mean, median and modal averages.  |
| b | Determine cumulative frequency, variance and standard deviation.                      |
| c | Describe and explain how statistical data is used in engineering and quality systems. |

**Assessment outcome 6: Use calculus to solve engineering problems**

- |   |   |
|---|---|
| a | Analyse, plot and interpret graphs to find the solution to engineering problems.  |
| b | Use differentiation and integration to determine the rate of change in engineering systems, for example position, velocity and acceleration; and to identify turning points, maximum, minimum and optimum values in practical engineering problems. |

## Assessment

This unit is assessed by an external examination set and marked by AQA. The examination takes place under controlled examination conditions and the exam dates are published at the start of each academic year.

Learners are allowed to use a non-programmable scientific calculator in the examination. Please note that, in line with typical practice within the engineering industry, learners are not expected to be able to recall formulae for use when answering questions that require mathematical calculations. They are expected to be able to select, manipulate (if required) and apply appropriate equations from provided formulae sheets.

The examination consists of a written paper with two sections, A and B. Learners have to complete both sections and there are no optional questions within either section.

The examination is 1 hour 45 minutes duration and the total number of marks available in the examination is 80.

Section A is worth 50 marks and consist of relatively short questions based on the whole of the specification for this unit. The learners will be required to answer all of the questions in Section A.

Section B is worth 30 marks and includes both short and longer answer questions worth up to 10 marks each. Each of these focus on a practical engineering context. The questions in Section B do not necessarily cover the whole of the specification for this unit at each assessment. Learners are required to answer all of the questions in Section B.

AQA will ensure that the full content of the unit is covered equally over the life of the qualification.

The delivery of the mathematical skills and approaches within this unit should be rooted within a range of practical engineering contexts. Some of this could be planned in the context of the learning activities and themes within the other units of this qualification or when visiting engineering companies. By using such examples, learners will be able to relate mathematics to real engineering.

## Synoptic assessment

This is an externally assessed unit. Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.

The amplification below identifies where the centre could consider synoptic learning and where learning from other units can be used to support the production of evidence for this unit.

This unit would logically be one of the last units taught and assessed, and there are opportunities for learners to use synoptic knowledge and learning from the other units on the qualification in their evidence for this unit.



## A01 Solve problems using the practical application of mathematics

There are topics in every unit which could be used to illustrate or apply the use of mathematics to solve engineering problems. For example:

- Unit 1 Materials technology and science AO1; the calculation of material properties from the stress-strain and load-extension graphs, and in AO3 the interpretation of equilibrium diagrams to determine phase changes and associated properties.
- Unit 1 Materials technology and science AO4; the use of mathematical methods to calculate values in electronic circuits.
- Unit 1 Materials technology and science AO5; the calculation of heat flows during the operation of heat pumps, calculation of changes in energy in engineering examples, and the application of the gas laws.
- Unit 2 Mechanical systems PO1; the calculation of mechanical advantage.
- Unit 2 Mechanical systems PO2; the selection of components based on their properties and the needs that they must address.
- Unit 2 Mechanical systems PO3; the application of statistical approaches to quality monitoring, such as statistical process control, and trend-based maintenance activities such as condition monitoring.
- Unit 4 Engineering design PO2 P7 and PO3 M5; the design calculations to address a product need.
- Unit 5 Production and manufacturing PO3 P7; the plotting and interpretation of data from approaches to quality control or condition monitoring to rectify the manufacturing process.
- Unit 6 Mechatronic project management PO2 M3; determining the cost and value benefits of a project, or using these to evaluate alternative options.
- Unit 7 Control systems PO2 M4 and PO3 M6; determining the operating characteristics of pneumatic and electronic systems.
- Unit 8 Programming for engineers PO4 P13 and P14; calculating movement requirements such as tool paths.

## A02 Use arithmetic to solve engineering problems

To develop their use of a wide range of common measures, learners should apply their knowledge from the following units:

- The quantification of material properties in Unit 1 Materials technology and science AO1 and AO2, and the calculation of values in circuits in AO4.
- The quantification of design requirements in Unit 2 Mechanical systems PO1 and PO2, Unit 4 Engineering design PO1 and PO2, and Unit 7 Mechatronic control systems PO1.
- The quantification of the properties of materials and components in Unit 2 Mechanical systems PO2 and Unit 4 Engineering design PO3.
- The quantification of product or process performance, in Unit 2 Mechanical systems PO3, Unit 4 Engineering design PO4 P12 and P13, and Unit 8 Programming for engineers PO4 P15 and D4.
- The estimation of project parameters and the selection of manufacturing approaches in Unit 6 Mechatronic project management PO2 M3 and P7, respectively.



### A03 Use algebra to solve engineering problems

When learning to rearrange equations and use them to solve engineering problems learners should apply their learning in the following units:

- The calculation of values in circuits in Unit 1 Materials technology and science AO4 and the calculation of heat transfer and the gas laws in AO5.
- The calculation of mechanical advantage in Unit 2 Mechanical systems PO1.
- Design calculations in Unit 4 Engineering design PO3 P8 and M5.
- Calculations of the operating characteristics of pneumatic and electronic systems in Unit 7 Control systems PO2 and PO3.

When interpreting changes in engineering systems from graphs, learners should apply their experience of interpreting the outcomes of the quality processes In Unit 2 Mechanical systems PO3 and Unit 5 Production and manufacturing PO3 P6, or condition monitoring in Unit 2 Mechanical systems PO3.

### A04 Use trigonometry and co-ordinate geometry to solve engineering problems

Vector addition and subtraction and conversion between polar and Cartesian co-ordinates can be taught concurrently with programming methods for CNC machines in Unit 5 Production and manufacturing PO2 P4, M4 and D3 and Unit 8 Programming for engineers PO4 P14, P15 and M8, in the context of plotting or calculating tool paths.

### A05 Use statistics to solve engineering problems

When manipulating and interpreting statistical data, learners should apply their knowledge and learning of the practical implementation of appropriate quality processes, such as statistical process control in Unit 2 Mechanical systems PO3 and Unit 5 Production and manufacturing PO3 or condition monitoring in Unit 2 Mechanical systems PO3.

### A06 Use calculus to solve engineering problems

When learning how to use graphs to solve engineering problems, learners should analyse stress–strain and load–extension graphs to calculate material properties in Unit 1 Materials technology and science AO1. They should also use equilibrium diagrams in Unit 1 Materials technology and science AO3.

The interpretation and use of graphs to find the solution to engineering problems should use learners' knowledge of the practical outcomes of quality processes in Unit 2 Mechanical systems PO3, and Unit 5 Production and manufacturing PO3 P6 and P7, and the analysis of trends shown by condition monitoring in Unit 2 Mechanical systems PO3.

## Delivery guidance

This unit content builds on prior learning in mathematics based on the National Curriculum requirements. It assumes that learners are able to:

- add, subtract, multiply and divide any number
- use the terms square, positive and negative square root, cube and cube root
- understand equivalent fractions, simplifying a fraction by cancelling all common factors
- use decimal notation and recognise that each terminating decimal is a fraction
- use percentages
- interpret fractions, decimals and percentages as operators
- divide a quantity in a given ratio
- approximate to specified or appropriate degrees of accuracy including a given power of 10, number of decimal places and significant figures

- recall and use properties of angles at a point, angles at a point on a straight line (including right angles), perpendicular lines, and opposite angles at a vertex
- understand and use the angle properties of parallel and intersecting lines, triangles and quadrangles
- recognise reflection and rotation symmetry of 2D shapes
- distinguish between centre, radius, chord, diameter, circumference, tangent, arc, sector and segment
- use 2D representation of 3D shapes
- measure and draw lines and angles
- draw triangles and other 2D shapes using a ruler and a protractor
- use calculators effectively and efficiently, including statistical functions.

## Employer engagement guidance

One method to develop employer engagement within this unit is to use visits to engineering companies. This could be in combination with activities for other units within this qualification. For example, if a visit is planned to an engineering company to look at materials, processing techniques and methods of quality control, the learners could also consider the mathematics that underpin the observed applications.

## Useful links and resources

Learners would benefit from reference to a standard Level 3 engineering mathematics text book. These might include:

- Davies H and Hicks G, *Mathematics for Scientific and Technical Students*, ISBN-10: 0582413885, Routledge, 2nd edition (25 Mar 1998)
- Croft A, Davison R and Hargreaves M, *Introduction to Engineering Mathematics*, ISBN-10: 0201624427, Prentice Hall, 1st edition (7 Feb 1995)
- Stroud K and Booth D, *Engineering Mathematics*, ISBN-10: 1137031204, Palgrave Macmillan, 7th edition (22 Mar 2013).

Learners may also benefit from the use of a book of standard formulae, such as:

- Greer A and Hancox D, *Tables, Data and Formulae for Engineers and Mathematicians*, ASIN: B00EKYO5P8, Nelson Thornes, 2nd edition (1988).

## National STEM Centre resources

We've worked with the National STEM Centre, the UK's leading science, technology engineering and maths (STEM) teaching and learning resources provider, to produce a free online digital library that's designed to support you in the delivery of examined units that are part of our Tech-levels in engineering.

[nationalstemcentre.org.uk/aqa](http://nationalstemcentre.org.uk/aqa)

## 12.4 Unit 4: Engineering design

<b>Title</b>	Engineering design
<b>Unit number</b>	D/506/6008
<b>Unit assessment type</b>	Centre assessed and externally quality assured
<b>Recommended assessment method</b>	Practical assignment  This is the preferred assessment method for this unit. A centre may choose an alternative method of assessment, but will be asked to justify this as part of the quality assurance process.
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	Communication (oral and written) and problem-solving <sup>2</sup>
<b>Resources required for delivering this unit</b>	To meet the needs of this unit it is essential that learners have, or have access to, some if not all of the following: <ul style="list-style-type: none"> <li>• manual drawing equipment</li> <li>• 2D and 3D commercial CAD software</li> <li>• extracts and illustrations from appropriate drawing standards and conventions</li> <li>• access to reference material which provides information about the physical and mechanical properties of materials</li> <li>• access to legislation and design standards</li> <li>• component and material suppliers' catalogues BS8888:2013 <i>Technical product documentation and specification</i>.</li> </ul>
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study.  Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.  This unit would logically be taught after Units 1, 2 and 5 (or concurrently with Unit 5) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.  The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

### Aim and purpose

Learners who complete this unit will develop an understanding of the engineering design process and will use industry standard tools and techniques to deliver an engineering design from start to finish.

<sup>2</sup> Please refer to Appendix A or visit the specification homepage to access the Transferable skills standards and associated guidance and recording documentation.

## Unit introduction

Design is the essential creative process of engineering, which distinguishes it from science, and which calls for imagination, creativity, the knowledge and application of technical and scientific skills, and skilful use of materials. The teaching of design has an integral place in the formation of all engineers.

The unit will prove the key knowledge and skills needed to be a design engineer:

- strong problem-solving skills
- a creative approach for generating new ideas
- a sound knowledge of computer assisted design (CAD) software
- an excellent grasp of engineering and design principles
- knowledge of the qualities of manufacturing parts and materials used in designs
- communication skills
- an understanding of manufacturing processes and construction methods
- an awareness of the environmental impact of design ideas.

This unit will assess learners understanding of the engineering design process (including all of the considerations and constraints a design engineer will face) and their ability to produce an engineering design using industry standard tools and techniques.

This unit provides an opportunity to evidence achievement of the transferable skills of communication (oral and written) and problem-solving.

## Unit content

### Customer requirements

Identify customer requirements

- Engineering design problem-solving:
  - explore design problems and identify ways of tackling them
  - planning and implementing ways of solving design problems
  - check design problems have been solved
  - review design problem-solving approach.
- Customer design briefs (CDB):
  - identify and describe the customer
  - description of the customer requirements including functional requirements and key customer benefits
  - key business goals including introduction timing, market share and desired financial performance
  - target market for the product
  - design constraints
  - stakeholders and their requirements that need to be included or considered in the development process.
- Product design specification document (PDS):
  - establish target specifications
  - analysis of competitive products
  - document customer requirements including:
    - physical dimensions
    - mass
    - operation and performance
    - production quantities
    - product life
    - market place positioning
    - product use and function
    - styling/aesthetics
    - ergonomic considerations
    - physical size
    - reliability
    - engineering system(s)
    - power
    - safety issues
    - materials and parts selection
    - materials and usage costing estimates
    - manufacturing constraints
    - legal and ethical considerations
    - maintenance
    - environmental considerations.

## Planning engineering designs

### Initial ideas and concept generation

- Design proposals:
  - sketching ideas for realistic design proposals, taking into account fitness for purpose, manufacturability, aesthetics and ergonomics:
    - freehand
    - digital
    - orthographic
    - isometric
    - oblique.
- Design considerations:
  - ergonomics
  - aesthetics
  - legislation and standards: relevant and current legislation, standards and codes of practice eg British Standards (BS), electromagnetic compatibility (EMC) directive, European legislation (European conformity (CE marking)), patent compliance
  - health and safety in the workplace eg *Health And Safety At Work Act*, *Control Of Substances Hazardous To Health* (COSHH) regulations
  - environmental considerations eg disposal, recycling and design for end of life
  - professional and ethical considerations
  - strength, weaknesses, opportunities and threats (SWOT) analysis
  - production ramp up considerations
  - manufacturing processes:
    - mass production
    - batch production
  - product lifecycle
  - sustainability.

## Producing detailed engineering designs

### Producing detailed engineering designs

- Selection of processes, components and materials:
  - construction process selection
  - materials selection
  - design calculations eg sizes of materials to meet strength requirements, electric motor power, electronic circuit performance, battery life.
- Detailed design production:
  - electrical design to BS8888
  - mechanical design to BS8888
  - regulatory compliance design including BS8888.
- Computer aided design (CAD).
- Final design solutions:
  - evaluation of proposals and selection of most appropriate for further development eg suitability for available manufacturing processes, cost effectiveness and visual appearance
  - development of design proposal into a feasible solution suitable for prototype manufacture eg specify materials, appropriate manufacturing processes, estimation of manufacturing cost, quality; conformity to relevant legislation and design standards
  - individual piece part definition (creation of manufacturing drawings for individual parts of an assembly).
- Presentation techniques:
  - 2D engineering drawings eg general arrangement drawing, assembly drawing, detail drawings, circuit diagrams, flow diagrams and schematic diagrams
  - drawing conventions and relevant British Standards
  - documentation eg design diary, log book and data sheets.

## Managing engineering designs

### Manage engineering designs

- Testing and refinement:
  - prototype fabrication
  - integration testing
  - regulatory testing
  - product documentation.
- Technical report production:
  - complete design documentation
  - user documentation
  - project evaluation.

## Performance outcomes

On successful completion of this unit learners will be able to:

Performance outcome 1:	Identify customer design requirements.
Performance outcome 2:	Plan engineering designs.
Performance outcome 3:	Produce detailed engineering designs.
Performance outcome 4:	Manage engineering designs.

## Grading criteria

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO1</b> <b>Identify customer requirements</b>	<b>P1</b> Describe the end user of the item being designed.		
	<b>P2</b> Produce a CDB to explore design <b>problems</b> , requirements and design constraints for a specific customer need.	<b>M1</b> Explore additional stakeholder requirements that may influence the CDB.	
	<b>P3</b> Produce a PDS that addresses a design <b>problem</b> that covers all of the key requirements using relevant terminology that demonstrates consideration of technical feasibility and costs.	<b>M2</b> Analyse similar products and possible manufacturing processes to inform the design specification.	
<b>PO2</b> <b>Initial ideas and concept generation</b>	<b>P4</b> Produce three concepts that address the design <b>problem</b> and meet a design brief, supported by high quality sketches and relevant technical information.		



Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P5</b> Identify relevant health and safety, environmental and legislative considerations for the design.		
	<b>P6</b> Produce a SWOT analysis of initial ideas to solve an engineering design problem.	<b>M3</b> Select and justify the final design concept.	
	<b>P7</b> Identify final technical information required for the design (eg physical dimensions, materials, processes etc).	<b>M4</b> Analyse technical and aesthetic design considerations to inform product design.	<b>D1</b> Assess design proposal for further development and modification for mass or batch production.
<b>PO3</b> <b>Produce detailed engineering designs</b>	<b>P8</b> Produce a CAD drawing that meets all elements of the CDB and PDS and complies with all relevant regulations, standards directives or codes of practice.	<b>M5</b> Justify the selection of manufacturing processes and the choice of the components and materials used for the design.	<b>D2</b> Design demonstrates mechanical functionality and integration of electrical components.
	<b>P9</b> Present design using appropriate techniques to different audiences with sufficient information to allow the customer(s) to assess it.		
	<b>P10</b> Produce and maintain design documentation.		
<b>PO4</b> <b>Manage engineering designs</b>	<b>P11</b> Produce a test plan that reflects all aspects of the design, highlighting where the design <b>problem</b> has been <b>solved</b> .	<b>M6</b> Identify design adjustments to reflect testing and potential for modification for mass or batch production.	<b>D3</b> Evaluate the importance of testing in engineering design.

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P12</b> Carry out relevant design tests.		
	<b>P13</b> Produce a <b>technical report</b> including an evaluation of the end-to-end design and <b>problem-solving process</b> .		

## Assessment amplification

This section provides amplification of what is specifically required or exemplification of the responses learners are expected to provide.

**In completing this unit, the process of problem-solving will be continually developed and reflected upon.**

**Learners will be presented with an opportunity to demonstrate the transferable skill of communication (oral and written) when completing P9 and P13.**

The following section contains guidance for centres on the unit grading criteria. This guidance is only provided where we feel that the criteria requires amplification of what is specifically required or exemplification of the responses learners are expected to provide.

Where guidance hasn't been provided it is felt that the grading criteria have been written in sufficient detail so that centres can fully understand the requirements of the assessment.

For **P2** learners should show evidence of having carried out the following activities to produce a customer design brief (CDB):

- identifying (with the client) the reasons or application for the design, and establish any constraints which may affect it
- identifying business goals
- identifying the target market for the product
- reviewing the critical operational/functional requirements and quality criteria of the design
- discussing any changes needed to suit the operational/functional requirements with the client
- recording the design brief in an appropriate information manner.

For **P3** the learner has to produce a product design specification (PDS). The design brief should be recorded as a computer based presentation, computer generated report or a relevant specific company document (if working with employers).

The PDS should include, at a minimum:

- product use and function
- operation and performance
- physical dimensions
- production quantities
- product life
- reliability
- power requirements
- safety issues
- materials and parts selection
- requirements for styling/aesthetics
- ergonomic considerations
- materials
- manufacturing constraints
- market place positioning
- maintenance requirements
- environmental considerations
- legal and ethical considerations.

For **M1** the additional stakeholders that the learner needs to consider should be both internal (eg technicians, assembly line staff etc) and external stakeholders (eg end users, customers).

For **D1** the learner has to look at how the design needs to be developed or modified for mass or batch production. This requires them to consider the suitability of the design against available manufacturing processes and its cost effectiveness.

For **P8** the design should identify relevant processes, components and materials, and contain mechanical and/or electrical details. The technical drawings should meet BS8888 requirements.

For **M5** the learner's justification should include an assessment of the manufacturing process on the design, covering, processes, parts and materials, eg the impact of higher quality parts or materials on cost and reliability, or how low quality parts or materials could make the design cheaper to achieve but impact upon the quality/reliability of the end product and its maintenance etc.

For **P10** the evidence may be in the form of design diary, log book, data sheets etc.

For **D3** the evaluation should cover how it benefitted their own design and also the way that testing is used in industry.

## Synoptic assessment

This unit would logically be taught after Units 1, 2 and 5 (or concurrently with Unit 5) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.

The amplification below identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

## P01 Identify customer requirements

When assessing how learners approach the exploration of design problems when creating the customer design brief in P2 and M1, and the production of a product design specification in P3 and M2, you should see evidence of them building on a consideration of the more limited range of criteria used in Unit 2 Mechanical systems PO1.

## P02 Generate initial ideas and design concepts

When learners identify environmental and legislative considerations in P5, they will be able to apply knowledge of the narrower technical range in Unit 2 Mechanical systems PO2 and PO3.

When researching technical information in P7 and M4, learners should apply the knowledge and understanding from the information gathering activities in Unit 5 Production and manufacturing PO4 P8.

When analysing data in P7 and M4, learners should apply their understanding from the consideration of the more limited range of criteria in Unit 2 Mechanical systems PO1. They should also use knowledge and understanding about manufacturing processes and scale of manufacture from Unit 5 Production and manufacturing PO1 (P1, M1) and PO2 (P2, M2), respectively, to carry out calculations applying their learning from Unit 3 Mathematics for engineers AO1.

When assessing learners' work on manufacturing processes and scale of manufacture in D1, you should be able to see knowledge and understanding applied from Unit 5 Production and manufacturing PO1 P1 and M1 and PO2 P2 and M2, respectively.

## P03 Produce detailed engineering designs

The understanding of the drawing conventions for P8 should be based on the practical use and interpretation of provided drawings in Unit 5 Production and manufacturing PO4 P8 and P9. Learners should also apply their learning about specialist technical knowledge for mechanical elements and the design of mechanical systems in Unit 2 Mechanical systems PO2 and PO3. Evidence of the learner's ability to produce engineering drawings may also be produced in Unit 5 Production and manufacturing PO2 P10 and M6.

When assessing the presentation of designs in P9, you should see evidence of techniques and presentation skills developed in Unit 2 Mechanical systems PO2 and PO3. These skills may also be developed in Unit 5 Production and manufacturing PO2 P10 and M6.

When considering the communication of preventative maintenance requirements in P10 learners should use their learning and knowledge of documentation developed in Unit 2 Mechanical systems PO3.

When assessing learners work selecting the manufacturing processes in M5, you should see the broader knowledge and understanding applied from Unit 5 Production and manufacturing PO1 P1, M1 and D1. Similarly, the choice of engineering components and materials in M5 should use the terminology and understanding developed in Unit 1 Materials science and technology AO1 and AO2 and any design calculations carried out should apply their learning from Unit 3 Mathematics for engineers AO1 and AO3.

The understanding of mechanical functionality for D2 should build on Unit 2 Mechanical systems PO1, PO2 and PO3.

## P04 Manage engineering designs

The use of test equipment in P12 should apply learners' knowledge and practical experience from Unit 2 Mechanical systems PO3, and Unit 5 Production and manufacturing PO3 P6.

If the testing in P12 uses graphical techniques, learners should apply their knowledge and understanding of graphical approaches from Unit 3 Mathematics for engineers AO1, AO5 and AO6.

When preparing the technical report for the designing in P13, learners should apply their knowledge and learning of the reporting required for design from Unit 4 Engineering design PO4 P13. For both P12 and P13, learners should apply their learning from Unit 3 Mathematics for engineers AO2 to quantify performance.

## Delivery guidance

The performance outcomes should, wherever possible, be delivered through hands-on activities involving engineering design. It is important that any design activities should have a valid 'real world' engineering context. Illustrative case studies on engineering product development can provide good support for learning within this unit, as a precursor to the hands-on experience.

**Performance outcome 1** involves identifying customer requirements, including the use of customer design briefs and product design specifications. It is important that the learner should understand the range of information that is required in the brief and specification to facilitate a design, although care must be taken not to anticipate the design solution at this stage.

**Performance outcome 2** develops the learner's ability to produce design ideas for an engineered product. Learners should understand how different types of sketch are used such as, for example, freehand sketching to communicate initial ideas and concepts, orthographic drawing to communicate dimensions etc. The impact of the design considerations could be effectively illustrated by visits to the design departments of local companies, presentations by visiting designers and product case studies.

**Performance outcome 3** develops learners' skills in producing and presenting detailed engineering designs, including the use of CAD drawing.

**Performance outcome 4** involves the management of the engineering design process. Learners should be able to produce and implement a test plan to evaluate a design. They should also be able to evaluate the process of designing, and recognise that the evaluations of the design and the process of creating it may have different evaluations.

## Essential resources

To meet the needs of this unit it is essential that learners have, or have access to, some, if not all, of the following:

- manual drawing equipment
- 2D commercial CAD software
- extracts and illustrations from appropriate drawing standards and conventions
- access to reference material which provides information about the physical and mechanical properties of materials
- access to legislation and design standards
- component and material suppliers' catalogues
- BS8888:2013 *Technical product documentation and specification*.

## Employer engagement guidance

The use of vocational contexts is essential in the delivery and assessment of this unit. Much of the work can be based around real engineering design requirements and drawings/specifications. In addition the use of engineering artefacts from employers is to be encouraged.

Employer engagement could be used to show learners how a new product design evolves, and how they approach product design.

Employers would be especially valuable in being able to talk to learners about successful designs that their organisations have been involved in, in the past, what factors made them successful, what lessons they learnt during the design process etc.

## Useful links and resources

Suppliers of CAD drawing software:

- Autodesk *Design the Future* program free resources:
  - free 3D design software: [autodesk.com/campaigns/design-the-future-uk/overview](https://autodesk.com/campaigns/design-the-future-uk/overview)
  - curriculum guides: [autodesk.com/campaigns/design-the-future-uk/curriculum](https://autodesk.com/campaigns/design-the-future-uk/curriculum)
  - teacher training: [autodesk.com/campaigns/design-the-future-uk/teacher-training](https://autodesk.com/campaigns/design-the-future-uk/teacher-training)
  - case studies: [autodesk.com/campaigns/design-the-future-uk/case-studies](https://autodesk.com/campaigns/design-the-future-uk/case-studies)
- Trimble SketchUp: [sketchup.com](https://sketchup.com)
- Creo: [ptc.com/communities/academic-program/products/ptc-creo](https://ptc.com/communities/academic-program/products/ptc-creo)
- Solidworks: [solidworks.co.uk/sw/products/free-cad-software-downloads.htm?scid=hp\\_acrd\\_dl\\_freecad](https://solidworks.co.uk/sw/products/free-cad-software-downloads.htm?scid=hp_acrd_dl_freecad)
- Spaceclaim: [dtsoftware.co.uk/spaceclaim.html](https://dtsoftware.co.uk/spaceclaim.html)
- Sketchfab: [sketchfab.com](https://sketchfab.com)
- Autodesk Design Academy:
  - the Autodesk Design Academy features a constantly growing collection of lessons, projects and curriculum support materials that help educators teach students creative confidence: [academy.autodesk.com/](https://academy.autodesk.com/)
  - projects challenge students to solve a specific problem using design thinking and software tools. Every project comes with resources that provide students with help and guidance: [academy.autodesk.com/curriculum?all\\_projects=projects](https://academy.autodesk.com/curriculum?all_projects=projects)
  - courses are in-depth explorations of how design works in a specific industry. These multi-week experiences are comprised of multiple projects and additional course material, along with lecture tools for teachers: [academy.autodesk.com/curriculum?all\\_courses=courses](https://academy.autodesk.com/curriculum?all_courses=courses)
- Autodesk Project Ignite: Project Ignite allows you to teach hands-on engineering projects which are integrated into Autodesk web applications such as TinkerCAD and Circuits [projectignite.autodesk.com/](https://projectignite.autodesk.com/)
- National STEM Centre [nationalstemcentre.org.uk/elibrary/](https://nationalstemcentre.org.uk/elibrary/)
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme: [stemnet.org.uk](https://stemnet.org.uk)
- The UK Schools Computer Animation Competition: [animation14.cs.manchester.ac.uk/](https://animation14.cs.manchester.ac.uk/)
- F1 in Schools: [f1inschools.com/](https://f1inschools.com/)
- WorldSkills: [theskillsshow.com/](https://theskillsshow.com/)
- The Young Engineers Network: [youngeng.org/](https://youngeng.org/)
- Institute of Engineering Designers: [ied.org.uk/](https://ied.org.uk/)
- Institute of Engineering and Technology: [theiet.org/](https://theiet.org/)
- IET Faraday resources: [faraday.theiet.org/resources/](https://faraday.theiet.org/resources/)

## 12.5 Unit 5: Production and manufacturing

<b>Title</b>	Production and manufacturing
<b>Unit number</b>	H/506/6009
<b>Unit assessment type</b>	Centre assessed and externally quality assured
<b>Recommended assessment method</b>	Practical assignment  This is the preferred assessment method for this unit. A centre may choose an alternative method of assessment, but will be asked to justify this as part of the quality assurance process.
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	Teamwork <sup>3</sup>
<b>Resources required for delivering this unit</b>	Learners should have access to a range of manufacturing processes, including computer controlled machines, so that they can become familiar with their safe operation.  It may also be advantageous to have a range of successfully engineered products available for product analysis, to assist learners in developing their understanding of the processes used to manufacture them.
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study.  Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.  This unit would logically be taught after Units 1, 2 and 4 (or concurrently with Unit 4) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.  The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

### Aim and purpose

The purpose of this unit is to provide learners with an understanding of the range of manufacturing processes and systems relevant to the production of multiple components. The learner will develop a production plan, schedule the production and work as part of a team to manufacture the batch of products.

<sup>3</sup> Please refer to Appendix A or visit the specification homepage to access the Transferable skills standards and associated guidance and recording documentation.



## Unit introduction

In many engineering contexts, products are manufactured in quantity. Engineers specify which manufacturing processes are required to convert the available forms of material into the finished products, and the systems to be used to support the production of consistent products. In this unit, learners will develop knowledge and understanding of a range of manufacturing processes and use these processes to plan and manufacture a batch of products.

In particular, the learner will develop knowledge of:

- manufacturing processes
- engineering manufacturing systems
- quality control and quality assurance
- engineering production planning
- performing production processes.

This unit provides an opportunity to evidence achievement of the transferable skill of teamwork.

## Unit content

### Manufacturing processes

- Material removal (wasting):
  - sawing
  - filing
  - turning
  - milling
  - drilling
  - punching
  - chemical etching.
- Shaping, including casting processes for metal:
  - sand casting
  - gravity die-casting
  - pressure die-casting.
- Forming, including the following processes:
  - press forming of metal sheet
  - plastics forming processes:
    - vacuum forming
    - injection moulding
    - blow moulding
    - extrusion
    - compression moulding
  - moulding of glass reinforced plastics (GRP) composite products.



## Manufacturing processes

- Joining methods:
  - for metal:
    - soft soldering
    - silver soldering
  - fusion welding processes:
    - oxyacetylene
    - manual metal arc (MMA)
    - tungsten inert Gas (TIG)
    - metal inert gas (MIG)
    - spot welding
  - friction welding
- mechanical joining methods:
  - screws
  - nuts and bolts
  - rivets
- adhesive bonding:
  - epoxy resin
  - cyanoacrylates
  - contact adhesives.
- Surface treatment and finishing:
  - galvanising
  - anodising
  - electroplating
  - polishing
  - painting
  - plastic coating
  - self-finishing.

## Engineering manufacturing systems

- Suitability of different types of manufacturing processes for different scales of manufacture:
  - one-off production
  - batch production
  - mass production
  - continuous production.
- The importance and operation of computerised manufacturing systems, including:
  - computer numerical control (CNC)
  - computer aided manufacturing (CAM)
  - computer aided engineering (CAE).
- Programming methods for CNC and CAM machines.

### Quality control and quality assurance

- The difference between quality control and quality assurance.
- The selection and use of measurement devices, including:
  - vernier callipers
  - micrometers
  - Go-No Go gauges
  - multimeters
  - automated measurement systems, including sensors for sizes, weights and colours.
- The theory and application of statistical methods in high-volume manufacturing, including:
  - statistical process control
  - Six sigma.

### Engineering production planning

- Production requirements and planning.
- Scheduling and Gantt charts.
- Risk assessments, identifying hazards, risks and control measures.
- The design, manufacture and use of jigs, fixtures, templates and moulds to support manufacturing.

### Performing manufacturing processes

- Safe working practices, including the use of appropriate personal protective equipment (PPE).
- How to carry out machining operations manually and using computer controlled equipment to produce components to specifications and tolerances.
- How to work as a member of a team to plan and manufacture multiple components.

## Performance outcomes

On successful completion of this unit learners will be able to:

Performance outcome 1:	Understand manufacturing processes.
Performance outcome 2:	Understand engineering manufacturing systems.
Performance outcome 3:	Understand and apply quality control and quality assurance.
Performance outcome 4:	Carry out engineering production planning.
Performance outcome 5:	Perform manufacturing processes.

## Grading criteria

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO1</b> <b>Understand manufacturing processes</b>	<b>P1</b> Select and justify at least <b>four</b> types of manufacturing processes to be used to produce your complex product. Each process must be different and be of the following types: <ul style="list-style-type: none"> <li>• wasting</li> <li>• shaping</li> <li>• forming</li> <li>• joining</li> <li>• surface treatment.</li> </ul>	<b>M1</b> Describe at least <b>three</b> advantages and disadvantages for each of the identified processes.	<b>D1</b> Compare the relative merits of the chosen processes with possible alternatives.
<b>PO2</b> <b>Understand engineering manufacturing systems</b>	<b>P2</b> Identify the most suitable scale of manufacture that could be used to produce your complex product and its component parts.	<b>M2</b> Justify the scale to be used to produce your complex product including an awareness of the commercial and economic context.	
	<b>P3</b> Describe the importance and operation (including programming) of at least <b>four</b> different applications of computerised systems in manufacturing.	<b>M3</b> Explain at least <b>four</b> advantages and <b>two</b> disadvantages of using computerised manufacturing systems.	<b>D2</b> Analyse the use of manual and computer controlled processes for the manufacture of a specific product with a justification of which process is most appropriate.
	<b>P4</b> Produce a simple program to manufacture a product using appropriate software.	<b>M4</b> Produce and virtually test a complex program to manufacture a product using appropriate software.	<b>D3</b> Evaluate the performance of a complex program when carrying out a manufacturing activity and improve its operation.

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO3</b> <b>Understand and apply quality control and quality assurance</b>	<b>P5</b> Demonstrate the difference between quality control and quality assurance.		
	<b>P6</b> Select and use appropriate measurement devices to ensure the quality of your complex product and record your findings.	<b>M5</b> Justify the use of the selected measurement devices.	
	<b>P7</b> Describe how statistical methods could be applied to the complex product if produced in high volume.		
<b>PO4</b> <b>Carry out engineering production planning</b>	<b>P8</b> As part of a <b>team</b> , locate, interpret and use information from technical literature to inform the choice of relevant materials, equipment, tools, processes or products, to be used to produce your complex product and its component parts.		
	<b>P9</b> Produce a production plan for your chosen product that provides the correct sequence of operations and process requirements, including a risk assessment identifying hazards, risks and control measures.		

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P10</b> As part of a <b>team</b> , design and produce a jig, fixture, template or mould to position or mark out the work piece in order to support the manufacture of your complex product.	<b>M6</b> Design and produce <b>two</b> or more of the following: <ul style="list-style-type: none"> <li>• jigs</li> <li>• fixtures</li> <li>• templates</li> <li>• mould</li> </ul> to position the work piece and guide the tools during the manufacture of your complex product.	
<b>PO5</b> <b>Perform manufacturing processes</b>	<b>P11</b> As part of a <b>team</b> , carry out manufacturing operations (including the correct use of relevant materials, equipment, tools, processes or products) to the appropriate standards and tolerances, following safe use procedures and use of appropriate PPE.	<b>M7</b> Explain how the processes could be adapted for production at higher volumes.	<b>D4</b> Evaluate the performance of the processes used to manufacture the product.
	<b>P12</b> Demonstrate the use of both manual and computer controlled equipment during the manufacture of your complex product.		

## Assessment amplification

**This section provides amplification of what is specifically required or exemplification of the responses learners are expected to provide.**

**Learners will be presented with an opportunity to demonstrate the transferable skill of teamwork when completing P8, P10 and P11.**

This unit will be assessed through a centre set and marked assignment. The assignment will take approximately 20 of the 90 guided learning hours available for this unit. Internal assessments are subject to moderation by AQA.

The learner must complete an assignment based on the production of a batch of complex products. This task will allow the learner to develop a production plan, schedule the production and work as part of a team to manufacture the batch of products.

The assignments produced by centres should be highly contextualised to their own resources.

**The complex product to be made should include components manufactured from at least two different classes of materials, plus an electronic and/or mechanical system.** For example, this could be a simple mechatronic device such as a robot hand or a simple automaton for a shop or museum display. The manufacture of the product should require a variety of different types of manufacturing processes. The manufactured batch should be at least six products.

The evidence submitted for assessment should include:

- a production plan, which includes justifications for process choices
- control programmes for computerised equipment
- a schedule for production (for example, in the form of a Gantt chart)
- risk assessments for the processes used
- a quality test record sheet
- a practical diary, including annotated pictures of any jigs, fixtures, templates and mould used and the batch of final products
- a witness statement covering safe working
- evidence of contributing as a team member.

## P01 Understand manufacturing processes

To achieve these assessment criteria, learners need to be aware of what constitutes a complex product. In this instance, a complex product should include components manufactured from at least two different classes of materials, plus an electronic and/or mechanical system.

To achieve **P1** learners should produce a production plan for the product to be manufactured in this assignment, describing the processes used and operational steps to manufacture and assemble the product. The production plan should include, but not necessarily be limited to, at least four different types of process.

To achieve **M1** the description should relate to the process capabilities and characteristics. This could be a column in their production plan or a separate report.

To achieve **D1** the comparison may be alternative methods (eg alternative methods of cutting a material) or alternative levels of automation (eg manual versus computer controlled processes). This could be a column in their production plan or a separate report.

## P02 Understand engineering manufacturing systems

To achieve **P2** this could be completed as a table of materials, listing each component and their appropriate scale of manufacture, or a separate report.

To achieve **M2** learners should justify the scale of manufacture identified for each item. This could be based on commercial usage, the economics of process (for example, by making a cost comparison with manual operations) or selection in terms of product quality.

To achieve **P3** learners should provide a general description covering at least **four** different applications of computerised systems in manufacturing, for example, for machining operations, product assembly, materials handling, identifying non-conforming products etc. This could, for example, be carried out as a report or essay.

To achieve **M3** learners should include within their report at least **four** advantages and **two** disadvantages of using computerised manufacturing systems, including comparisons with manual processes.

To achieve **D2** learners should analyse how the use of manual and computerised manufacturing systems could affect the production of either the product they are making or of a named commercial product. This should include a recommendation of which approach to use, justified in terms of product quality, production rates and process economics.

To achieve **P4** learners should provide a copy of their program, identifying the key features. The program may be a simple sequence of instructions for a single-pass manufacturing operation.

To achieve **M4** learners should provide a copy of their program, identifying the key features. The program should include either conditional statements (for example, an if... then... statement to check that the tool has returned to the datum point and correct this if necessary), sub-routines (for example, repeating a series of coordinates in a multi-pass operation) or tool changes.

For **P4** and **M4** learners can choose whichever software is relevant to the task or to suit the equipment they are using.

To achieve **D3** learners should use a program to carry out a manufacturing activity and evaluate and improve its performance. This may involve reducing the time required to carry out the operation, improving the finish of the product or improving the dimensional accuracy, as appropriate.

## P03 Understand and apply quality control and quality assurance

To achieve **P5** either the learner's production plan or the quality test records, such as a sheet recording test or measurement results for key features, should include a statement explaining the difference between quality control (QC) and quality assurance (QA).

To achieve **P6** the learners' quality test records should show that they have used a variety of appropriate QA and QC devices to check the product that they are making. For example, this could include Go-No Go gauges and vernier callipers for dimensions, and a multimeter to check a circuit.

To achieve **M5** learners should justify the use of the selected measurement devices in terms of the accuracy required by the relevant feature and the impact this has on QC and QA.

To achieve **P7** learners should describe how a statistical approach such as statistical process control or Six sigma could be applied for at least one appropriate feature of the product being manufactured.

## P04 Carry out engineering production planning

To achieve **P8** learners should reference the sources of information used from technical literature, for example on the characteristics of the processes or tools to be used, along with identifying the team member who obtained this information. This could be, for example, within their production plan where the information is used or as a separate table of information used.

To achieve **P9** learners should create a production plan that lists the processes to be carried out (in the correct sequence). This should include the tools to use, quality tests and health and safety requirements. They should also produce risk assessments for any machines used, identifying any significant hazards, risks and appropriate control measures. There should be sufficient detail that a third party could manufacture the product.

To achieve **P10** as a member of a team, the learner should participate in the design and manufacture of a jig, fixture, template or mould to position or mark out the work piece during one operation in the production of their product. Team members could either each produce a simple item, such as a shape template, for a different operation within their production plan or they could participate in the process of jointly designing and making a more complex item (for example, one team member may design a positioning jig, with others carrying out different manufacturing operations to create and assemble the parts of it). They should provide photographic evidence of the manufactured item.

To achieve **M6** learners should design and make at least **two** different types of device (jig, fixture, template or mould) to support the production of their product. This could include devices for work positioning and/or tool guidance, such as drilling jigs. They should provide photographic evidence of the manufactured items.

## P05 Perform production processes

To achieve **P11** the learner should carry out machining operations to manufacture a batch of at least six products. This could be evidenced by an annotated picture of the batch of final products or a witness statement.

To achieve **M7** the learner should explain how processes could be adapted for production at higher volumes, for example, through the increased use of fixtures or computer controlled equipment. This could be evidenced by commentary within their production plan, a diary of the practical work undertaken, or appropriate annotations on a picture of the batch of final products.

To achieve **D4** the evaluation should identify possible improvements. This could be evidenced by a diary of the practical work undertaken, commentary on test record sheets, or appropriate annotations on a picture of the batch of final products.

To achieve **P12** the learner should carry out machining operations using manual controlled and computer controlled processes. This can be evidenced by an annotated picture of the batch of final products or a witness statement.

## Synoptic assessment

This unit would logically be taught after Units 1, 2 and 4 (or concurrently with Unit 4) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.

The amplification below identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.



## P01 Understand manufacturing processes

When demonstrating their understanding of manufacturing processes for P1, M1 and D1, learners should apply knowledge and understanding of constraints PO1 P2 and the capabilities of manufacturing processes PO3 M5, from Unit 4 Engineering design. Similarly, evidence presented showing the relationship between the process and the materials used should apply the terminology and learning developed in Unit 1 Materials science and technology AO1 and AO2.

## P02 Understand engineering manufacturing systems

When assessing learners' work about scale of manufacture in P2 and M2, you should be able to see knowledge and understanding of constraints applied from Unit 4 Engineering design PO1 P2.

When programming CNC machines involving the use of different numbering systems, this should apply learners' knowledge of using mathematics to solve engineering problems from Unit 3 Mathematics for engineers AO1.

In the context of plotting or calculating tool paths when programming CNC machines in P4, M4 and D3, vector addition and subtraction and conversion between polar and cartesian coordinates can be taught concurrently with Unit 3 Mathematics for engineers and learners should be able to evidence learning from AO1 and AO4.

## P03 Understand and apply quality control and quality assurance

When assessing how learners test components in P6, P7 and M5, you should look for evidence of them applying their knowledge of test equipment from Unit 4 Engineering design PO4 P12, and their practical experience of testing from Unit 2 Mechanical systems PO3.

When using graphical methods for plotting and interpreting data from approaches to quality control in P6 and P7, learners should apply their understanding developed in Unit 3 Mathematics for engineers AO1, AO3, AO5 and AO6.

## P04 Carry out engineering production planning

When assessing learners' work for researching technical information in P8, you should be able to see knowledge and understanding applied from the information gathering activities in Unit 4 Engineering design PO2 P7 and M4.

When planning assembly operations involving pneumatic or electrical components in P9, learners should apply their knowledge and understanding from Unit 2 Mechanical systems PO3.

When assessing how learners consider risk assessment and the implementation of safety rules in the workshop in P9, you should consider how they apply knowledge and practical experience developed in Unit 2 Mechanical systems PO3.

When producing design ideas for the jigs and fixtures in P10 and M6, learners should use the skills and understanding from generating a range of design ideas in Unit 4 Engineering design PO2 P4. When producing engineering drawings of their design, they should apply their knowledge and learning, with the addition of conventions and representations specific to this technology from Unit 4 Engineering design PO3 P8 and P9.

## P05 Perform manufacturing processes

When assessing learners' work for manufacturing operations or assembling components in PO5 P11, P12, M7 and D4, you should be able to see knowledge and skills applied from Unit 2 Mechanical systems PO2 and PO3.

When assessing how learners implement safety rules in the workshop for P11, learners should apply knowledge and learning developed in Unit 2 Mechanical systems PO2 and PO3. Similarly, when assessing the learners' knowledge of relevant rules and regulations you should look for evidence of them applying knowledge and learning developed from their consideration during design in Unit 4 Engineering design PO2 P5 and Unit 7 Advanced design for manufacture PO3 P6, P7 and M4.

## Delivery guidance

The delivery of the content within this unit should be rooted within a range of practical engineering contexts. It is anticipated that learners will develop understanding of a broad range of processes through their practical application. Examining the way in which materials are processed to manufacture real products will also make a substantial contribution to learners' understanding.

Some of this unit could be planned in the context of the learning activities and themes within the other units of this qualification, or visits to engineering companies, or the use of industrial contacts and manufacturers to provide visiting lectures. By using such examples, learners will be able to relate the content to real engineering.

## Employer engagement guidance

Employer engagement within this unit could be developed through visits to engineering companies to look at different processing techniques and methods of quality control.

Additionally, the brief for the manufactured product could be developed in conjunction with a local employer, for example manufacturing a prototype batch for a potential new product or replicating a product manufactured in large quantities using batch manufacturing.

## Useful links and resources

At the time of publication, there are no textbooks which fully cover the specific topics in this unit. However, some relevant content can be found in the following:

- Thompson R, *Manufacturing processes for Design professionals*, ISBN-10: 0500513759, Thames and Hudson, (15 Oct 2007)
- Lefteri C, *Making It: Manufacturing Techniques for Product Design*, ISBN-10: 1856697491, Laurence King, 2nd edition (27 Feb 2012)
- Norman E, Cubitt J, Urry S and Whittaker M, *Advanced Design and Technology*, ISBN-10: 0582328314, Longman, 3rd edition (28 Sep 2000).

## 12.6 Unit 6: Mechatronic project management

<b>Title</b>	Mechatronic project management
<b>Unit number</b>	R/506/6023
<b>Unit assessment type</b>	Centre assessed and externally quality assured
<b>Recommended assessment method</b>	Practical assignment  This is the preferred assessment method for this unit. A centre may choose an alternative method of assessment, but will be asked to justify this as part of the quality assurance process.
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	Communication (oral and written) and research <sup>4</sup>
<b>Resources required for delivering this unit</b>	Centres will call on resources used for the other units in this qualification where learners make a mechatronic item in order to follow the project plan. Learners may use specialist computer software and equipment to plan, monitor and present the project but it is not always essential to use it.
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study.  Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.  This unit would logically be taught at the end of the course and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.  The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

### Aim and purpose

To devise, manage and complete an independent project to produce a mechatronic system and then to communicate a summary of the project to an audience.

<sup>4</sup> Please refer to Appendix A or visit the specification homepage to access the Transferable skills standards and associated guidance and recording documentation.

## Unit introduction

This unit will draw on the knowledge and expertise gained while studying the other units of the Level 3 Technical Level in Mechatronic Engineering. The learner will develop and make a mechatronic system and then present their project outcomes to an audience where they will evaluate the design as well as their own performance.

On completion of this unit, the learner will have gained skills in project management as well as communication and presentation skills.

The specific aim of this unit is to train learners in mechatronic engineering project management. Having successfully completed the module, learners will be able to apply project management methodology to mechatronic engineering problems.

This unit provides an opportunity to evidence achievement of the transferable skills of communication (oral and written) and research.

## Unit content

### Understanding the requirements for managing and controlling engineering projects effectively

Application of project management techniques to engineering problems	<ul style="list-style-type: none"> <li>• Project planning techniques (eg critical chain project management, agile project management, lean project management).</li> <li>• Budget planning and control.</li> <li>• Resource allocation.</li> <li>• Lean and agile manufacture.</li> </ul>
Monitoring and supervision techniques	<ul style="list-style-type: none"> <li>• Project risk management.</li> <li>• Project management software.</li> <li>• Supervisory and management techniques used within engineering organisations.</li> </ul>
Reporting and communication techniques	<ul style="list-style-type: none"> <li>• Reporting methods.</li> <li>• Documentation.</li> <li>• Written methods eg notes, sketches and drawings.</li> <li>• Recording initial concepts eg lists, notes, mind mapping, flow diagrams and sketches.</li> <li>• Planning: long-term planning eg planners, charts and scheduling techniques (flow charts, Gantt charts, critical path methods, software packages).</li> </ul>

## Planning engineering projects

Project planning	<ul style="list-style-type: none"> <li>• Concept planning:             <ul style="list-style-type: none"> <li>• group discussion</li> <li>• brainstorming</li> <li>• mind mapping</li> <li>• research – selecting, gathering, evaluating and synthesizing information from a range of sources.</li> </ul> </li> <li>• Identifying project objectives.</li> <li>• Identifying the activities needed to complete objectives.</li> <li>• Scheduling the activities in their logical sequence.</li> <li>• Estimating resource requirements.</li> <li>• Estimating time and cost.</li> <li>• Integrating technical and commercial requirements.</li> <li>• Developing the budget and recognising contingencies.</li> <li>• Stakeholder analysis, including users, and support personnel for the project.</li> <li>• Risk planning.</li> <li>• Quality assurance/testing planning.</li> </ul>
Engineering project considerations	<ul style="list-style-type: none"> <li>• Producing engineering specifications.</li> <li>• Selection of manufacturing processes, process routes and manufacturing facilities for typical components and assemblies:             <ul style="list-style-type: none"> <li>• relevant tool and equipment selection</li> <li>• comparing costs of tool use and downtime</li> <li>• selected manufacturing processes</li> <li>• manufacturing process route</li> <li>• planning of manufacturing facilities.</li> </ul> </li> </ul>
Engineering business considerations	<ul style="list-style-type: none"> <li>• Legislation.</li> <li>• Health and safety issues.</li> <li>• Quality standards.</li> </ul>
External considerations	<ul style="list-style-type: none"> <li>• Political.</li> <li>• Social.</li> <li>• Economic.</li> <li>• Technological.</li> <li>• Environment.</li> <li>• Geographical.</li> </ul>

## Managing engineering projects

Project implementation	<ul style="list-style-type: none"> <li>• Direct and manage project execution.</li> <li>• Proper use of resources (eg equipment, tools, materials) and techniques within agreed timescale.</li> <li>• Quality assurance of project outcomes.</li> <li>• Distribute information to stakeholders.</li> <li>• Testing project outcomes against the initial design.</li> </ul>
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**Managing engineering projects**

Project monitoring	<ul style="list-style-type: none"> <li>• Quality checking methods eg analytical and measurement techniques, inspection, tolerances and performance testing.</li> <li>• Monitoring the project variables (cost, effort, scope etc) against the project plan and engineering specification.</li> <li>• Measure and control project costs.</li> <li>• Measure and manage safety.</li> <li>• Recording and analysing data or performance records.</li> <li>• Modifying/updating charts/planners, technical decisions and information.</li> <li>• Recording project goals and milestones.</li> </ul>
Project maintenance	<ul style="list-style-type: none"> <li>• Identify corrective actions to address problems, issues and risks.</li> <li>• Project adjustments/correction of errors.</li> <li>• Updates of the project plan.</li> <li>• Continuing communication with stakeholders.</li> </ul>

**Evaluating engineering projects**

Evaluation of project against engineering specification	<ul style="list-style-type: none"> <li>• Target/actual comparison.</li> <li>• Customer/stakeholder feedback.</li> </ul>
Evaluating project outcomes	<ul style="list-style-type: none"> <li>• Cost benefit analyses.</li> <li>• Value benefit analyses.</li> <li>• Expert surveys.</li> </ul>

**Presenting project information**

Communication project outcomes	<ul style="list-style-type: none"> <li>• Communicating information and conclusions effectively in a variety of written and oral formats.</li> <li>• Presentation format, style, language and vocabulary choices to suit audience (eg oral, written and display presentation software, photographs, video, models, blogs and magazine/booklet).</li> <li>• Delivering technical information to an audience including engineers and non-engineers.</li> </ul>
Project report	<ul style="list-style-type: none"> <li>• Project report: log book/diary record of all events.</li> <li>• Written technical report including relevant drawings/circuit diagrams, sketches, charts and graphs.</li> <li>• Use of information and communication technology (eg CAD, DTP) as appropriate to present findings.</li> </ul>

**Performance outcomes**

On successful completion of this unit learners will be able to:

Performance outcome 1:	Understand the requirements for managing and controlling mechatronic projects effectively.
Performance outcome 2:	Plan mechatronic projects.
Performance outcome 3:	Manage mechatronic projects.
Performance outcome 4:	Evaluate mechatronic projects.
Performance outcome 5:	Present project information.

## Grading criteria

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO1</b> <b>Understand the requirements for managing and controlling engineering projects effectively</b>	<b>P1</b> Describe project management techniques that aid reporting and communication with examples of their application.	<b>M1</b> Compare and contrast different project management methodologies.	<b>D1</b> Select and justify an appropriate project delivery methodology.
	<b>P2</b> Identify <b>four</b> supervisory techniques which may be used to achieve engineering objectives within an organisation.	<b>M2</b> Compare and contrast different supervisory techniques.	
<b>PO2</b> <b>Plan engineering projects</b>	<b>P3</b> Carry out <b>research</b> , using a variety of different sources, to inform project planning.	<b>M3</b> Justify costs and resources to inform project planning.	
	<b>P4</b> Locate, interpret and use information from technical engineering literature.		
	<b>P5</b> Produce an effective project plan that identifies all objectives and correctly orders all activities, resources, risks and quality checks.	<b>M4</b> Interpret commercial, technical, and stakeholder requirements.	
	<b>P6</b> Provide an engineering working instruction that explains workshop and laboratory practice techniques to be used in the delivery of the project.		

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P7</b> Select effective methods, materials, equipment, tools, processes and products to ensure that operations and maintenance take place efficiently and to the appropriate standards.		
	<b>P8</b> Outline the relevant legal requirements, codes of practice and industry standards governing engineering activities, including personnel, health, safety, risk and environmental issues.	<b>M5</b> Produce a political, economic, social and technological (PEST) analysis to support the project plan.	
<b>P03</b> <b>Manage engineering projects</b>	<b>P9</b> Demonstrate the correct use of materials, equipment, tools, processes, or products.	<b>M6</b> Achieve project objectives using the agreed level of resources and demonstrate the effective and efficient management of project to meet deadlines.	<b>D2</b> Independently manages all aspects of project delivery to the required standards identifying efficiencies, time savings and/or improvements to the original project plan.
	<b>P10</b> Apply appropriate quality processes including putting processes and resources in place to manage potential risks from the project.		



Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P11</b> Carry out project adjustments to ensure projects are delivered to the appropriate standards and communicate these to supervisor.		
<b>PO4</b> <b>Evaluate engineering projects</b>	<b>P12</b> Evaluate project outcomes including the extent to which the outcomes of the project were achieved and the costs and benefits resulting from the completion of the project.	<b>M7</b> Demonstrates the use of stakeholder feedback in project evaluation.	<b>D3</b> Evaluate the whole project process, making recommendations for future improvements.
<b>PO5</b> <b>Present project information</b>	<b>P13</b> Produce coherent and well-structured project records and final <b>report</b> .		
	<b>P14</b> <b>Present</b> information and project evaluation to <b>two</b> different audiences, fully reflecting the audiences' needs in terms of format, style and language.		

## Assessment amplification

This section provides amplification of what is specifically required or exemplification of the responses learners are expected to provide.

Learners will be presented with an opportunity to demonstrate the transferable skill of research when completing P3.

Learners will be presented with an opportunity to demonstrate the transferable skill of communication (written and oral) when completing P13 and P14.

In this unit learners must complete a project relating to the production of a mechatronic system.

Ideally, the project brief should be set by an employer in a relevant industry sector; however it could be set by supervisors within the centre (college/school), with appropriate industrial support and input, if that is not possible. The involvement of employers at this stage will ensure that learners follow realistic projects and designs and will give the learner the best possible opportunity to develop his/her capabilities as a mechatronic engineer.

The project provides an opportunity to apply and practice skills and techniques learned in previous units as well as investigating and developing new areas of interest to support the project objectives.

The projects can address a wide variety of topics, dependent upon the available employers, the resources available to the centre, or the learners own areas of interest. However, it must be relevant to mechatronic engineering and the fusion of mechanical and electronic elements, with computer control.

It is anticipated that the evidence submitted for assessment will include:

- a project plan
- an engineering specification
- a list of the resources required
- a production plan
- risk assessments
- progress records/project diary, including any test records
- annotated pictures of the finished product
- a project report that includes descriptions and comparisons of project management techniques
- a presentation (either PowerPoint, video, magazine feature or blog and/or image capture)
- witness statements.

**Performance outcome 1** is related to project management techniques. Learners must demonstrate that they understand, and can identify, management and supervisory techniques that they will meet while undertaking their project and those they might meet in industry. It is envisaged that the output from this performance outcome P1, P2, M1, M2 and D1 will be written and form a section of the final report.

To achieve **P1** learners should describe techniques that specifically aid reporting and communication. This should refer to techniques used both in industry and for individual projects. Their comparison in **M1** can inform the chosen delivery methodology used for the project in **D1**.

For **P2** learners could compare supervisory techniques such as, for example, delegation, giving instructions or advice. To achieve M2, they should compare these approaches.

**Performance outcome 2** is related to all aspects of planning the project and the mechatronic device before it is manufactured.

For the concept planning required in **P3** it is envisaged that the learner will discuss ideas or use some form of idea generation method, such as brainstorming, rather than produce scale models.

For **P4** learners should provide a summary of the information used and where it was found during their literature research. To achieve M3 the learner must demonstrate that their research has used a range of sources – an online search of the latest literature or examples of mechatronics projects is not sufficient. The use of technical journals or other publications, symposium reports or information gathered from interviews with practising engineers and subject experts is expected to form part of the submitted evidence.

For **P5, P6 and P7** the learner must plan the project in detail. The plan need not necessarily be one document but could be made up of a timetable or scheduling plan, flow charts and priority calculations.

These can be produced using proprietary software or sketched out by hand. Whichever method, or combination of methods, is chosen, the output must be sufficiently legible for assessment by both internal and external assessors.

**P5** also asks the learner to identify the resources required to complete the project. This could include specific manpower, machinery and other equipment plus use of workshops, room hire and any necessary travel. Resources required for research should also be listed.

To achieve **P7** the learner's plan must explain why the resources selected (eg materials, tools and equipment) are suitable and how these will ensure that the appropriate standards are met.

To achieve **P8** the learner should outline the main elements of legislation, codes of practice and industry standards relevant to not only their project but also those that govern all engineering activities. This should include health and safety issues as well as environmental issues, such as disposal and reuse considerations.

To achieve **M4** the learner must demonstrate that the needs of stakeholders have been considered, including considerations of the final user of the mechatronic device and any commercial stakeholder requirements. This may be developed through industry input where a joint industry-academic project is being carried out. This should consider the potential commercial manufacture of the project item including both internal business considerations and external considerations. These may be informed by the estimates of costs from **D2** and discussed in the final project report in **P13**, incorporating stakeholder feedback in **M7**.

For **M5** the analysis should show how political, economic, social and technological influences could affect the project and the subsequent commercial viability of the product.

For **D2** the cost justification should include all of the resources identified for **P5**. It is expected that the estimated cost of materials will be based on realistic costs obtained from up-to-date supplier catalogues. Where the cost of only large quantities of materials is known then these can be divided down to obtain the cost of the small quantities required to complete the project. This should also consider the estimated production costs, using hourly rates for all personnel that may be required, as well as estimates for services. The justification could be in relation to alternative feasible materials and processes, or in relation to the difference between manufacturing a prototype/development batch and a product in volume.

**Performance outcome 3** covers the monitoring and recording of all aspects of the project plan to ensure deadlines are met and standards maintained during the manufacture of the product.

For **P9, P11, M6 and D3** evidence could be provided by practical diaries, witness statements, and annotated comments on the project plan. This could also include the use and reporting of key performance indicators and the monitoring of specific project variables.

To achieve **P10** it is expected that the learner will identify quality control points within the production schedule, and use appropriate measurement devices and inspection techniques.

**Performance outcome 4** involves evaluating the outcome of the project and Performance outcome 5 involves presenting information about the project.

For **P12** it is expected that the outcomes assessed will include conformance to the project schedule. Where deadlines or changes to manufacture are required these should also be noted; if no changes are required then this too must also be noted. This should also consider how well the mechatronic system developed in the project meets the initial specification, including the functional requirements.

For **M7** this could be evidenced by written notes from a meeting or interview with the client or by written feedback, such as a letter. There needs to be a response to the feedback received in order to demonstrate how it has been used, for example to make changes to the design or manufacturing proposal.

For **D4** the evidence could be included within the final report in **P13** or the presentations in **P14**.

To achieve **P13** the learner should produce coherent and well-structured project records as well as a final project report. It is expected that the report be written in a technical manner and include relevant drawings/circuit diagrams, sketches, charts and graphs, as well as a bibliography and contents listing.

For **P14** the different audiences could be, for example, the industrial client or potential investors in the developed product, and students who are planning to undertake similar projects. The presentation of the project to one of the two audiences should be in the form of a traditional spoken lecture, enhanced by the use of presentation software. However, the learner could deliver their second presentation in another format, for example a video presentation or other use of multimedia. The learner may also wish to consider social media to present their findings such as a blog (which may be available to all or only through a controlled environment), Twitter or writing a project summary for publication in a magazine or newspaper.

## Synoptic assessment

This unit would logically be taught at the end of the course and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.

The amplification below identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

Please note that PO1: Understand the requirements for managing and controlling mechatronic projects effectively, has content unique to this unit and does not have synoptic links with the other units in this qualification.

## P02 Plan mechatronic projects

When assessing the research and use of technical information in P3 and P4, you should see understanding and skills applied from Unit 4 Engineering design PO2 P7 and M4 and understanding applied from the information gathering activities in Unit 5 Production and manufacturing PO4 P8, and Unit 8 Programming for engineers PO4 P13.

Where learners produce engineering drawings to support P6, they should apply their understanding of the drawing conventions based on the practical use and interpretation of provided drawings in Unit 5 Production and manufacturing PO4 P8 and P9. The production of CAD drawings should apply learning from Unit 4 Engineering design PO3 P8 and the specialist technical knowledge for mechanical elements as well as the design of mechanical systems in Unit 2 Mechanical systems PO2 and PO3. Learners will also be able to develop the ability to produce engineering drawings in Unit 7 Mechatronic control systems PO2 P4 and PO3 P8, and Unit 5 Production and manufacturing for PO2 P10 and M6.

Whilst considering the requirements of the design of the outcome of their project generally, learners should apply their understanding from Unit 4 Engineering design PO1 and PO2, the design considerations for control systems in Unit 7 Mechatronic control systems PO1 and design issues specific to the use of programmable logic controllers (PLCs) in Unit 8 Programming for engineers AO4 P13 and M6.

When assessing how learners determine the cost and value benefits of a project or estimating the project parameters or using these to evaluate alternative options in M3, or selecting manufacturing approaches in P7, you should look for learners applying their learning from Unit 3 Mathematics for engineers AO1.

When assessing how learners demonstrate the consideration of stakeholders in M4, you should see an understanding of exploring stakeholder requirements applied from Unit 4 Engineering design PO1 M1.

When assessing how learners apply environmental and legislative considerations to their own project in P8, you should see learners apply their knowledge from Unit 2 Mechanical systems PO2 and PO3 and Unit 4 Engineering design PO2 P5. Additionally, when assessing risk assessment and the implementation of safety rules in the workshop, you should see the knowledge and practical experience the learner has developed applied from Unit 2 Mechanical systems PO3, Unit 5 Production and manufacturing PO4 P9, and Unit 8 Programming for engineers PO3 P11.

### P03 Manage mechatronic projects

When assessing manufacturing operations or assembling components in P9, you should see knowledge and skills applied from Unit 2 Mechanical systems PO2 and PO3, and Unit 5 Production and manufacturing PO5 P11, P12, M7 and D4.

When assessing the application of quality systems for P10, you should see an understanding applied from Unit 5 Production and manufacturing PO3 P5 and P6.

### P04 Evaluate mechatronic projects

When assessing the evaluation of the overall project in P12 and D3, you should look for evidence of how learners apply their understanding of how testing and evaluation is applied to products from Unit 2 Mechanical systems PO3, Unit 4 Engineering design PO4 P12, and practical experience from Unit 5 Production and manufacturing PO3 P6. Depending upon the design, this may also link with the testing and subsequent improvements carried out in Unit 7 Mechatronic control systems PO2 M3 and D2 plus PO3 M5 and D3, and Unit 8 Programming for engineers PO4 P15.

### P05 Present project information

When assessing the documentation required for a full design and make project in P13, you should see understanding of the design documentation needed applied from Unit 4 Engineering design PO3 P10 and PO4 P13, and knowledge of documentation requirements applied from Unit 2 Mechanical systems PO3.

When assessing the suitability of the presentation of design work for different audiences in P14, you should see knowledge and understanding developed for design activities applied from Unit 4 Engineering design PO3 P9.

## Delivery guidance

Learners will be using knowledge and skills gained in Units 1 to 7 to complete their project. The choice of project should be left to the learner but it may be influenced by the activities they have carried out in Unit 3 Engineering design or Unit 5 Control systems. However the work submitted should not be a straight copy of assessment material for these units but should build on these foundations and be unique.

It is essential to start delivery of this unit with Performance outcome 1 (understanding how to manage a project) so that learners are able to understand the consequences for their choices within Performance outcome 2 (the plan). Performance outcome 3 (managing the project) should be delivered in parallel as elements from this will influence design decisions and corrections during the project and the final project direction. Evidence of these design decisions and project outcomes completed during Performance outcomes 2 and 3 will feed into the content of the presentation required for the final performance outcome.

The delivery of the unit will be mostly practical with some revisiting of theory gained in the previous units.

## Employer engagement guidance

An industry view of mechatronic project management would be helpful for the completion of this unit and so liaising with local companies is recommended. Local specialist companies can be a useful resource for examples of various types of company documentation (including project plans and industry standard engineering specifications) as well as demonstrating a vocational understanding of methods used to resolve problems met during projects and uses of project planning software. These same industry contacts can also provide useful feedback to the final learner presentation.

Ensuring support from local companies is embedded into the delivery will greatly assist with learner engagement and provide a better understanding of project management within the mechatronics industry. Additionally, the design aspects of the project could be developed in conjunction with a local employer.

Centres should also be in contact with professional institutions most of which have education officers who can arrange volunteers to give talks, demonstrations and visits.

## Useful links and resources

- Applegarth M and Posner K, *Project Management Pocketbook*, ISBN 9781903776872, UK, 2008 (2nd revised edition)
- Bowden J, *Writing a Report*, ISBN 9781845284701, UK, 2011 (9th edition)
- Etherington B, *Presentation Skills for Quivering Wrecks*, ISBN 9781904879800, UK, 2006
- Mechatronic Tips: [mechatronictips.com](http://mechatronictips.com)
- The Institute of Engineering and Technology Faraday Education website with free STEM teaching resources: [faraday.theiet.org/resources/](http://faraday.theiet.org/resources/)
- School Grants Scheme run by The Institute of Physics, The Institute of Engineering and Technology and The Science and Technology Facilities Research Council. Grants of up to £500 for projects or events linked to the promotion of physics or engineering for students aged up to 19: [iop.org/about/grants/school/page\\_38824.html](http://iop.org/about/grants/school/page_38824.html)
- mechatronics project examples from the Northwestern University (Illinois, USA): [mechatronics.design.wiki.hades.mech.northwestern.edu/index.php/Main\\_Page](http://mechatronics.design.wiki.hades.mech.northwestern.edu/index.php/Main_Page)



## 12.7 Unit 7: Mechatronic control systems

<b>Title</b>	Mechatronic control systems
<b>Unit number</b>	Y/506/6024
<b>Unit assessment type</b>	Centre assessed and externally quality assured
<b>Recommended assessment method</b>	Practical assignment  This is the preferred assessment method for this unit. A centre may choose an alternative method of assessment, but will be asked to justify this as part of the quality assurance process.
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	N/A
<b>Resources required for delivering this unit</b>	Centres will need access to electrical and mechanical workshops and to a wide range of components and test equipment. Reference books, video/ DVD and access to the internet should be available.
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	<p>It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study.</p> <p>Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.</p> <p>This unit would logically be taught after Units 1, 2, 3, 4, 5 and 8 (or concurrently with Units 3 and 8) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.</p> <p>The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.</p>

### Aim and purpose

The purpose of this unit is to give learners an understanding of control systems and how they function and operate within a mechatronic system. It will enable learners to design and construct a control system for a given purpose.

### Unit introduction

Mechatronics is the 'fusion' of mechanical and electronic elements, with computer control. Typically, the mechanical element is responsible for creating or transmitting motion within the mechatronic device; and the electronic element is responsible for determining or providing the instructions for the operation of the system in response to inputs, based on the computer control. Either element can be supplemented or at least partially replaced by a pneumatic or hydraulic element, dependent upon the requirements of the application.

In this unit learners will explore the various types of control system, understanding the function of the components within them, the conventions used to express them and how they can be assembled to create a working system. The unit would be particularly useful to the learner embarking on, or contemplating, the career of mechatronic technician, operations and maintenance technician, design technician and many other associated occupations.

Learners will examine the elements that constitute a control system and how the measurement, control and actuation systems work together. Learners will design and build a control system with pneumatic elements and examine electronic control systems with PLC and microcontroller controls. They will design and build a control system with electronic components utilising either PLC or microcontrollers.

## Unit content

### Control systems and mechatronics

#### Mechatronic systems

- The definition of a mechatronic system.
- Typical mechatronic control systems.
- Sensors found in a mechatronic system:
  - thermometer
  - pressure sensor
  - light dependent resistor
  - volt meter
  - ammeter
  - micro switch
  - accelerometer.
- Typical applications of mechatronic devices.
- Overview of control theory:
  - the use of input, process and output building blocks
  - signals
  - open and closed loop feedback
  - subsystems
  - systems block diagrams.
- Types of control system, their components, capabilities, limitations and typical applications:
  - fluid power: pneumatics and hydraulics
  - mechanical: cam timers
  - electronic: microcontrollers and PLCs
  - combinations of electronic and fluid power control systems.
- Design requirements for control systems in mechatronic applications.
- How energy flows through mechatronic control systems.
- Producing a specification for the control system in a mechatronic device.
- Methods of assessing the performance of the control system in a mechatronic device.



## Designing and building a pneumatic control system

### Pneumatic systems

- Types of pneumatic component and their function:
  - main air supply
  - exhaust air
  - air pipes
  - push button activator
  - plunger activator
  - lever activator
  - single acting cylinder
  - double acting cylinder
  - 3/2 valve
  - 5/2 valve
  - reservoir
  - unidirectional restrictor
  - spring return
  - pressure regulators
  - solenoid activated directional control valve.
- Designing pneumatic systems:
  - circuit diagrams
  - modelling pneumatic systems using CAD software.
- Making functional pneumatic systems:
  - methods of component assembly
  - pipework connections
  - leak detection
  - flow regulation.
- Testing pneumatic systems:
  - pressure gauge
  - flow meter
  - leak detection.
- The operation of pneumatic systems:
  - pressure and pressure regulation
  - temperature
  - directional movement
  - flow
  - thrust
  - force
  - area
  - ratio.

## Designing and building an electronic control system

### Electronic systems

- Types of electronic component and their function:
  - contact switches
  - light dependant resistors (LDRs)
  - photodiodes
  - microphones
  - thermistors
  - diodes
  - light emitting diodes
  - light dependent resistors
  - resistors
  - variable resistors
  - fuse
  - capacitors
  - PLC
  - microcontroller
  - OP amp.
- Designing electronic systems:
  - circuit diagram
  - circuit simulation software.
- Making functional electronic systems:
  - methods of assembly
  - methods of making printed circuit boards
  - soldering
  - de-soldering
  - joining cables
  - attaching components
  - circuit testing.
- Testing electronic systems:
  - multimeter
  - oscilloscope/PC simulation.
- The operation of electronic system:
  - signal
  - current
  - voltage
  - PLC
  - variable speed drives
  - switches.

## Performance outcomes

On successful completion of this unit learners will be able to:

Performance outcome 1:	Understand what a control system is.
Performance outcome 2:	Design and build a pneumatic control system.
Performance outcome 3:	Design and build an electronic control system.

## Grading criteria

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO1</b> <b>Understand what a control system is</b>	<b>P1</b> Describe <b>three</b> different examples of mechatronic control systems.		<b>D1</b> For a given mechatronic control system, justify choice and use of two control system components.
	<b>P2</b> Examine and explain control theory using annotated diagrams and an identified control system example.	<b>M1</b> Explain the way in which a specific sensor input results in the action for a given mechatronic control system.	
	<b>P3</b> Outline the operation of <b>three</b> different types of sensor used within an identified mechatronic control system.		
	<b>P4</b> Describe, with the aid of a systems diagram, the energy flow through an identified mechatronic control system.	<b>M2</b> Explain what happens to the signal in a given mechatronic control system as it passes through the controller.	

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO2</b> <b>Design and build a pneumatic control system</b>	<b>P5</b> For a given design brief, design a suitable mechatronic system to meet the desired outcomes. Select and describe the pneumatic components and technology in the system designed.	<b>M3</b> Test the pneumatic components of the control system constructed and record the results of the test in an appropriate format.	<b>D2</b> Using the test results, suggest improvements or modifications that could be made to the control system you have constructed.
	<b>P6</b> Describe the control and output actions of the pneumatic components of the designed system.		
	<b>P7</b> Construct the pneumatic components of the control system you have designed using appropriate methods.	<b>M4</b> Explain the way in which the pneumatic components within your control system operate to provide the required outcome.	
<b>PO3</b> <b>Design and build an electronic control system</b>	<b>P8</b> For a given design brief, design a suitable mechatronic system to meet the desired outcomes. This will require the selection of appropriate electronic components and control technology.	<b>M5</b> Test the electronic components of the control system you have constructed.	<b>D3</b> Evaluate the control system you have constructed, covering how well the system meets the given brief and how testing supported any improvements made.
	<b>P9</b> Use a systems block diagram to describe the electrical components in the control system you have designed.	<b>M6</b> Explain the way in which the electrical components within your control system operate to provide the required outcome.	

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P10</b> Describe the function of a PLC or microcontroller within the control system you have designed.	<b>M7</b> Explain how the PLC or microcontroller impact on the components.	
	<b>P11</b> Construct the electrical elements of the control system you have designed using appropriate methods. Use photographs or videos to support the evidence of your construction.		

## Assessment amplification

**This section provides amplification of what is specifically required or exemplification of the responses learners are expected to provide.**

Evidence of performance outcomes can be collected from a variety of sources such as assignments, practical activities, written reports and witness statements/observation records.

The pass grade indicates the minimum level of performance required by the learners. Assessment must cover all of the performance outcomes. Achievement of a merit or distinction grade will require learners to submit work that demonstrates additional depth and breadth in the subject being assessed.

### P01 Understand what a control system is

To achieve **P1** learners should select three different mechatronic systems and describe them, explaining clearly what it is about the system that makes it a mechatronic system. The evidence could be presented in the form of a report supported by annotated diagrams or sketches.

To achieve **P2** learners should select one mechatronic system and then draw a diagram explaining the key principles of control theory. Whilst learners are not expected to cover all aspects of control theory, they should demonstrate an understanding of open and closed feedback loops, subsystems and the principles of input, process and output. The diagram should show which components are part of the input, process and output elements of the system.

To achieve **P3** learners should identify a common control system with multiple sensors. The learner should then select three different types of sensor within the system and describe the operation of the three different types of sensor. The learner will need to name and give a brief overview of the mechatronic system and sketches or diagrams showing the operation of the components, along with written commentary on the operations would be an appropriate way to present the information.

To achieve **P4** learners will need to understand how the signal flows through a mechatronic system. The learner will identify a common mechatronic system (the one used for P3 would be appropriate) and then identify the way in which signals pass through the system in different modes. The learner will describe the signal progression, the components involved and the effect of different conditions on the signal. The evidence could be presented as a series of annotated diagrams or a flow chart with supporting text.

To achieve **M1** learners should understand the process by which input into a sensor results in a change in the output from an actuator. The learner will identify a specific component and explain how the input signal is modified and used to modify the actions of two different actuators. The evidence could be presented in the form of one or more annotated diagrams with a written explanation.

To achieve **M2** learners will need to give detail on the signal conditioning element of a control system. The learner will select and name the mechatronic system and explain what happens as the signal passes through the controller.

To achieve **D1** learners will need to understand the different choices of control system component available. The learner will select and identify a mechatronic system and identify two key control system components within the mechatronic system. The learner will suggest a justification for the use of the two components. As part of the justification, the learner is expected to consider the use of alternative components.

## P02 Design and build a pneumatic control system

To achieve **P5** learners should be given a suitable design brief to design a control system that includes pneumatic components. In the assignment learners will design one system to meet the brief that comprises both pneumatic and electrical components. To ensure both pneumatic and electrical elements are covered, they will be assessed separately.

To achieve **P6** the learners need to describe the separate measurement, control and actuation of the pneumatic elements of the system they have designed. Annotated diagrams or photographs may be a suitable way of presenting this.

To achieve **P7** learners will construct the pneumatic control system they have designed. Learners will use a range of appropriate techniques in a safe manner. Video or photographic evidence may be appropriate in this instance.

To achieve **M3** learners will undertake appropriate tests on the pneumatic control system constructed. The evidence could be presented in the form of a table.

To achieve **M4** learners will develop P6 and P7 and explain how the different pneumatic components in the control system they have constructed operate together. Good answers will demonstrate the interdependence of the different components.

To achieve **D2** learners will need to consider the control system constructed holistically and develop the answers for M3 and M5 using the tables created to suggest any improvements that could be made to the overall system. The suggestions must be logical and based upon evidence.

## P03 Design and build an electronic control system

To achieve **P8** learners should be given a suitable design brief for which they design a control system that includes electrical components. It should be noted that P03 refers to the electrical control system only; however, the mechatronic system designed may also include mechanical or pneumatic elements.

Whilst it is possible for learners to design one system containing both pneumatic and electrical components to meet the requirements of both P02 and P03, to ensure both pneumatic and electrical elements are covered, they will be assessed separately.

To achieve **P9** learners should clearly identify the inputs, processes, outputs and signals that operate within the system, along with any feedback loop.

To achieve **P10** learners will need to understand how PLCs and microcontrollers are integrated into electrical control systems. The actual programming of PLCs is dealt with elsewhere and this unit gives a practical application of that unit. Learners should describe the function of the PLC or microcontroller within the system they have designed.

To achieve **P11** learners will construct the electronic control system they have designed. Learners will use a range of appropriate techniques in a safe manner. Video or photographic evidence may be appropriate in this instance.

To achieve **M5** learners will undertake appropriate tests on the electrical control system constructed. The evidence could be presented in the form of a table.

To achieve **M6** learners will develop P9 and P10 and explain how the different electrical components in the control system they have constructed operate together with the PLC or microcontroller. Good answers will demonstrate the interdependence of the different components.

To achieve **M7** learners will need to explain how the use of a PLC or microcontroller in the design has affected the selection of other components. For example, this could include the need for diodes to protect against back EMF, relays to facilitate the operation of higher power outputs, or resistors to limit current.

To achieve **D3** learners will need to consider the control system constructed holistically and carry out an evaluation of the mechatronic control system.

The evaluation will consider component selection, construction, performance, ease of maintenance and how well the system performs specified operations. The correct size and operation of components, expected life of components and cost of maintenance should all feature in the evaluation. The evaluation could be presented in the format of a report which may include appropriate diagrams.

There are two example assignments given here that demonstrate how the full range of performance outcomes might be covered.

**Note:** the examples given are not mandatory but serve to illustrate the minimum complexity required.

### Example assignment 1

Performance outcomes P1, P2, P3, P4 and M1 can be completed through an assignment producing a report based on the examination of the components and function of the identified mechatronic systems.

The assignment will require a research activity on at least three mechatronic systems with multiple sensors, control systems and actuators. The investigation will look at the range of components and use the application of mathematics to determine or confirm the values in the system. The report could contain an annotated diagram using the appropriate abbreviations, units and symbols. The report will include detail on how energy flows through the systems in different circumstances.

The assignment can be extended to cover performance outcomes M2 and D1 by including a description of how signals are modified and the justification of the use of the components based on comparison with alternatives.

## Example assignment 2

Performance outcomes P5, P6, P7, P8, P9, P10, P11, M3 and M5 can be completed through the learner undertaking the design, construction and testing of a control system to meet a given design specification. The learners will need to identify the requirements to meet the given brief, select the appropriate combination of pneumatic and electrical components and use either a PLC or microcontroller as the processor for the control system. Learners will then construct the system using appropriate methods and techniques.

The selection of an appropriate brief is essential here. The brief should require a combination of pneumatic and electrical components to be used. The brief will require the use of a PLC or a microcontroller; however, the program for the PLC or microcontroller would be given. The programming of PLCs is dealt with in Unit 8 Programming for engineers. It is possible to combine the two units and for learners to use a PLC created in Unit 8 Programming for engineers as part of this design.

A document explaining how the system was designed, constructed and tested would be suitable and should be supported by photographic or video evidence.

The assignment can be extended to cover performance outcomes M4, M6, M7, D2 and D3 by including the testing and optimisation of the system supported by an evaluation report explaining how the system optimisation was carried out, how the system meets the design brief and any further suggestions for improvements. It should be noted that whilst D2 and D3 are aligned with PO3, these two criteria should be dealt with holistically and relate to the whole system and include both pneumatic and electrical aspects.

## Synoptic assessment

This unit would logically be taught after Units 1, 2, 3, 4, 5 and 8 (or concurrently with Units 3 and 8) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.

The amplification below identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

### PO1 Understand what a control system is

The learning of different examples of mechatronic control systems in P1 should be taught concurrently with the applications of PLCs in Unit 8 Programming for engineers PO1 P3.

When assessing knowledge and understanding of control theory in P2 and M1, and signal processing in M2, you should see learners applying their learning and understanding from Unit 8 Programming for engineers PO1 P3, PO2 P5, P8 and M3, and PO3 P10.

When assessing the analysis of control systems in D1, you should be able to see understanding of types of mechanical component (such as seals, springs etc) applied from Unit 2 Mechanical systems PO2.

### PO2 Design and build a pneumatic control system

When assessing the design brief and exploring design problems in P5, you should be able to see knowledge of the design process in a broader context applied from Unit 4 Engineering design PO1 P2, P3, M1 and M2. They should also build on the more limited range of criteria used in Unit 2 Mechanical systems PO2.

When producing a design idea in P5, learners should use the skills and understanding from generating a range of design ideas in Unit 4 Engineering design PO2 P4. When they are producing engineering drawings of their design, learners should apply their knowledge and learning from Unit 4 Engineering design PO3 P8 and P9, with the addition of conventions and representations specific to this technology.



They may also apply drawing skills developed in Unit 5 Production and manufacturing PO4 P10 and M6, and Unit 6 Mechatronic project management PO2.

When assessing learners' descriptions of the actions of pneumatic components in their design in P6 and M4, you should be able to see knowledge of types of motion and methods of transmitting force between different types of motion applied from Unit 2 Mechanical systems PO1.

When assessing how learners construct pneumatic systems in P7 and explain their operation in M4 and D2, you should look for how learners apply their understanding of types of mechanical component (such as seals, springs etc) from Unit 2 Mechanical systems PO2. Depending upon the design, they may also apply their learning of assembly methods from Unit 2 Mechanical systems PO2.

When assessing how learners test components in M3, you should look for how they apply their knowledge of test equipment from Unit 4 Engineering design PO4 P12, and their practical experience of testing from Unit 2 Mechanical systems PO3 and Unit 5 Production and manufacturing PO3 P6 and M5.

When explaining the selection and operation of components in M4, learners should apply their knowledge of pneumatic control systems and the gas laws from Unit 1 Materials technology and science AO5, and apply their knowledge from Unit 3 Mathematics for engineers AO1 and AO3 to determine the operating characteristics of the system.

### P03 Design and build an electronic control system

When assessing the design brief and exploring design problems in P8, you should be able to see knowledge of the design process in a broader context applied from Unit 4 Engineering design PO1 P2, P3, M1 and M2. They should also build on the more limited range of criteria used in Unit 2 Mechanical systems PO2.

When producing design ideas in P8, learners should use the skills and understanding from generating a range of design ideas in Unit 4 Engineering design PO2 P4. When they are producing engineering drawings of their design, learners should apply their knowledge and learning from Unit 4 Engineering design PO3 P8 and P9, with the addition of conventions and representations specific to this technology. They may also apply drawing skills developed in Unit 5 Production and manufacturing PO2 P10 and M6, and Unit 6 Mechatronic project management PO2.

When integrating electrical components into a design in P8, P9 and M6, learners should apply their understanding from Unit 4 Engineering design PO2 P4 and P7. If their design includes electrical drives, they should apply their understanding from Unit 2 Mechanical systems PO2.

When assessing the use of microcontrollers in P10, M6 and M7, you should be able to see knowledge and understanding applied from Unit 8 Programming for engineers PO1 P2, P3, M1 and D1, and PO2 P8 and M3.

When testing components in M5, learners should apply their knowledge of test equipment from Unit 4 Engineering design PO4 P12, and their practical experience of testing from Unit 2 Mechanical systems PO3 and Unit 5 Production and manufacturing PO3 P6 and M5. Depending upon the design, this may also link with the testing carried out in Unit 8 Programming for engineers PO4 P15.

When explaining the selection of components in M6, learners should apply their knowledge of calculating values in electronic circuits from Unit 1 Materials technology and science AO4, and apply their knowledge from Unit 3 Mathematics for engineers AO1 and AO3 to determine the operating characteristics of the system.

When assessing the evaluation of the performance of their electronic system in D3, you should be able to see learners' understanding applied from Unit 4 Engineering design PO4 P13.

## Delivery guidance

The performance outcomes should be, wherever possible, delivered through the inspection, dismantling and observation of mechatronic control systems and their components; with an emphasis on developing transferable skills to other different or more complex systems. It is important that the learner be exposed to complex systems from the first day of the course in order that she or he may see the relevance of each subsystem as it is being discussed.

The performance outcomes may be taken in any order, however, it would seem appropriate to follow the order as presented.

**Performance outcome 1** is an overview of mechatronic systems and components. It will require research on mechatronic systems with the different properties being explored as they occur. Suitable mechatronic systems include, but are not restricted to:

- lifts and escalators
- manufacturing robots for assembly or packing
- white goods such as washing machines
- sorting systems for letter or parcels
- CNC machines
- fluid level controls in tanks
- antilock braking systems on cars
- oven temperature controls
- laser guided missiles
- robotic painting systems
- food processing systems
- level crossing control.

Many of these systems may be observed at a basic level by examining the functions of mechatronic systems in the centre's workshops. Wherever possible the learner should be exposed to and assessed on systems used in local industry. A manufacturing or process operation would be ideal for research purposes.

Learners should also be taught a range of generic functions performed by mechatronic control systems. These include, but are not restricted to:

- emergency stop
- compensation
- selection
- identification.

When considering actuators, learners should be taught about the different types of motor they may come across. These are covered in detail in the mechanical unit.

Learners must be taught different ways of presenting the information they have, circuit diagrams are a useful tool and the learners should be taught the common electrical and pneumatic symbols.

**Pneumatic symbols include:** main air supply, exhaust air, diaphragm activator, pilot air, solenoid activator, air pipes connected, spring return, air pipes not connected, single acting cylinder, air bleed, double acting cylinder, 3/2 valve and 5/2 valve, push button activator, reservoir, plunger activator, shuttle valve, pressure indicator, thermometer, flow meter.

**Electrical symbols include:** open switch, closed switch, cell, lamp, battery, voltmeter, resistor, ammeter, variable resistor, thermistor, light dependent resistor (LDR), fuse, diode, light emitting diode (LED).

Whilst covering this performance outcome it would be sensible to cover detail on design. The learners' understanding of design specifications and design briefs is assessed in Performance outcomes 2 and 3 but could be presented during the research of the mechatronic systems.

**Performance outcome 2** develops the learners' ability to design and construct a control system that meets a specific design brief. Focusing on the pneumatic elements of the control system it would be advisable to build upon the principles and components from the previous learning outcome. Learners will examine existing designs of pneumatic mechatronic control systems and circuits and then design a control system with a significant pneumatic content. For the 'make' element learners will need to develop appropriate skills in assembling pneumatic components. This will include a range of pipework skills. They will also need to learn fault-finding techniques to test the completed circuit.

**Performance outcome 3** focuses on electronic control systems and the role of PLCs and microcontrollers. The programming of PLCs is dealt with in a separate unit; in this unit it is the way in which the PLC or microcontroller is integrated into the electrical control system that is important. Learners will need to design a control system with a significant electrical component controlled by a PLC or microcontroller. Learners will need to be taught a range of skills appropriate for assembling the electronic circuit, including soldering, de-soldering and a range of cable joining techniques.

## Essential resources

Centres will need access to electrical and mechanical workshops and to a wide range of components and test equipment. Reference books, video/DVD and access to the internet should be available.

## Employer engagement guidance

Liaison with local industry is to be strongly recommended. Seek out their assistance in providing work placements or visits; invite specialist personnel to visit the centre and give talks on various aspects of their company relating to control systems. They can also be a valuable resource for sample systems both working and damaged, each of which can be used for training purposes.

Centres should also be in contact with professional institutions, most of which have education officers who can marshal a team of volunteers to give talks, demonstrations and arrange visits.

A recent report, published in January 2014 and commissioned by CfBT, on employer engagement may be found on their website at: [cfbt.com/en-GB/Research/.../2014/r-employer-engagement-2014](http://cfbt.com/en-GB/Research/.../2014/r-employer-engagement-2014)

## Useful links and resources

- BBC Bitesize: [bbc.co.uk/schools/gcsebitesize/design/systemscontrol/pneumaticsrev1.shtml](http://bbc.co.uk/schools/gcsebitesize/design/systemscontrol/pneumaticsrev1.shtml)
- A comprehensive list of pneumatic symbols can be found at: [roymech.co.uk/Useful Tables/Drawing/Hyd Pnue symbols.html](http://roymech.co.uk/Useful_Tables/Drawing/Hyd_Pnue_symbols.html)
- IET Discussion forum on robotics [theiet.org/communities/robotics/](http://theiet.org/communities/robotics/)

## 12.8 Unit 8: Programming for engineers

<b>Title</b>	Programming for engineers
<b>Unit number</b>	D/506/6025
<b>Unit assessment type</b>	Centre assessed and externally quality assured
<b>Recommended assessment method</b>	Practical assignment  This is the preferred assessment method for this unit. A centre may choose an alternative method of assessment, but will be asked to justify this as part of the quality assurance process.
<b>Guided learning hours</b>	90
<b>Transferable skill(s) contextualised within this unit</b>	Research <sup>5</sup>
<b>Resources required for delivering this unit</b>	Centres will need access to programmable logic controller (PLC) based equipment and simulation software located in a laboratory environment. Access to industrial applications of PLCs and utilising local companies to include visiting speakers with PLC experience, will also be essential. There will need to be a wide range of components and test equipment available. Reference books, video/DVD and access to the internet should be available.
<b>Meaningful employer involvement</b>	It is a requirement that all learners undertake meaningful activity involving employers during their study and this activity will be scrutinised as part of our ongoing quality assurance activities with centres.
<b>Synoptic assessment</b>	It is a requirement that all learners undertake meaningful synoptic learning and assessment during their study.  Depending upon the order in which the units are delivered, there are opportunities for learners to use elements of other units to support the development of knowledge and learning for this unit.  This unit would logically be taught after Units 1, 2, 3, 4, 5 and 7 (or concurrently with Units 3 and 7) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.  The assessment amplification within the unit identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

### Aim and purpose

The purpose of this unit is to give learners an understanding of the role of PLCs in a modern industrial context. The emphasis of the unit is for learners to develop programming techniques whilst at the same time giving them an understanding of the hardware capabilities of PLCs. Learners will also develop the tools required for developing good PLC solutions to industrial problems.

<sup>5</sup> Please refer to Appendix A or visit the specification homepage to access the Transferable skills standards and associated guidance and recording documentation.

## Unit introduction

PLCs have become fundamental to all aspects of industrial control and have demonstrated their robust and dependable nature in a wide variety of industrial setting that can be very hostile environments.

The unit will enable learners to write small working computer programs in response to given briefs that take inputs, make decisions and control outputs. The unit will provide a foundation in practical programming skills, problem-solving, data structures, algorithms and program design. This unit covers the fundamentals of digital logic and an introduction to PLCs in engineering systems with a focus on automated systems and the appropriate programming languages. Learners will develop an understanding of the role PLCs play within engineering systems or subsystems. They will also learn basic elements of PLC functions by writing small programs and testing these programs on an actual system. Learners will learn to identify malfunctioning PLCs, as well as to apply troubleshooting strategies to identify and localise problems caused by PLC hardware.

Learners will examine the background of PLCs and develop an understanding of where PLCs can be employed and the types of tasks they can be customised to perform. They will develop the ability to program PLCs to perform a number of tasks. It is envisaged that tasks will be devised that will develop use of the full range of commands. Learners will develop an understanding of the range of connectivity that is available with the standard PLC and the process that can develop good solutions to problems using a professional and rational approach. It is thought that many programs and applications are developed very much in an ad hoc fashion which is not the most productive and efficient process.

This unit provides an opportunity to evidence achievement of the transferable skill of research.

## Unit content

### The role of programmable logic controllers in engineering systems and subsystems

PLCs in a contemporary context

- The history and development of PLCs.
- The main PLC types that are available.
- Industrial applications of PLCs:
  - controlling process
  - controlling aspects of machines (eg maintaining the integrity of the guarding)
  - controlling automated production lines
  - controlling conveyers.
- The nature of PLCs to operate in industrial conditions versus a typical PC.
- Advantages/disadvantages of PLCs.
- Hardware.
- I/O interfaces.
- Typical devices that the PLC can control:
  - sensors
  - actuators
  - electric motors
  - pneumatic and hydraulic cylinders
  - relays
  - solenoids.

## The principles of computer programming

Fundamental programming techniques	<ul style="list-style-type: none"> <li>• Application software and connectivity.</li> <li>• Simple graphical programs: creating programs with simple graphical user interfaces.</li> <li>• Program structure: definition of data and methods; programs with one or more methods.</li> <li>• Logic gates.</li> <li>• A modular approach.</li> <li>• Defining inputs, processes and outputs.</li> <li>• Defining modules, subroutines and parameter passing.</li> <li>• Define validation and error checking processes.</li> <li>• The offline programming languages used in PLCs (eg linear, structured, ladder, statement lists and logic function blocks).</li> <li>• The common PLC numbering systems (eg binary, octal, decimal, hexadecimal and binary coded decimal (BCD)).</li> <li>• The different programming codes used to identify factors (eg safety interlocks/guards and sensor inputs, actuator and other outputs, process management and auxiliary functions).</li> </ul>
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## The basic operation of a PLC and its connectivity

Programmable engineering systems	<ul style="list-style-type: none"> <li>• Fundamental operation of a PLC; how the PLC processes the program:               <ul style="list-style-type: none"> <li>• function and design of a PLC</li> <li>• types of signals in control systems</li> <li>• number systems and digital logic</li> <li>• program processing.</li> </ul> </li> </ul>
Configuration of a PLC	<ul style="list-style-type: none"> <li>• Basic function modules of PLCs.</li> <li>• How to access the specific programming software.</li> <li>• The use of manuals and related documents to set-up, solve problems and aid the efficient programming of PLCs.</li> </ul>
The safe use of PLCs in engineering	<ul style="list-style-type: none"> <li>• Safety issues.</li> <li>• Regulations.</li> <li>• The basic set-up and operation of the computer system and any peripheral devices that are used.</li> <li>• The correct start-up and shut down procedures to be used for the computer system.</li> </ul>
Preventive and routine maintenance of PLCs	<ul style="list-style-type: none"> <li>• Troubleshooting of the PLC hardware within a module or system.</li> <li>• How to deal with system problems (such as error messages received, peripherals which do not respond as expected).</li> <li>• The checks to be carried out to ensure that peripheral devices are connected correctly.</li> <li>• The correct procedure to shut down the operating and programming system.</li> <li>• The problems that can occur with the downloading and running of PLC programs, and how these can be overcome.</li> </ul>

## Producing computer programs for use in engineering

Solving engineering problems	<ul style="list-style-type: none"> <li>• Defining the problem (eg client discussions, talking to users).</li> <li>• Investigation of possible solutions:             <ul style="list-style-type: none"> <li>• available hardware</li> <li>• investigating existing systems</li> <li>• new technology.</li> </ul> </li> <li>• Developing solutions:             <ul style="list-style-type: none"> <li>• brainstorming</li> <li>• feasibility checks.</li> </ul> </li> <li>• Making a choice from the possible solutions.</li> <li>• Agreeing proposals.</li> <li>• Solution specification.</li> </ul>
Programming the solution	<ul style="list-style-type: none"> <li>• The information and data required in order to produce complete and accurate PLC programs.</li> <li>• How to extract and interpret general and technical data and information from different sources (eg drawings, computer models, symbols and conventions, BS or ISO standards) in order to produce the PLC program for process control.</li> <li>• The factors to be taken into account when producing PLC programs:             <ul style="list-style-type: none"> <li>• the type of PLC (fixed I/O, modular, rack mounted)</li> <li>• PLC control capabilities</li> <li>• safety</li> <li>• the product/environment being controlled by the process.</li> </ul> </li> <li>• How to produce effective and efficient programs to avoid unnecessary operations.</li> </ul>
Testing and simulation of a PLC program	<ul style="list-style-type: none"> <li>• Testing:             <ul style="list-style-type: none"> <li>• modules</li> <li>• sub routines</li> <li>• overall system</li> <li>• user testing</li> <li>• functional testing</li> <li>• simulation of the operating conditions</li> <li>• methods and procedures to check that the completed program will control the required parameters safely, accurately and efficiently.</li> </ul> </li> </ul>
Storing PLC programs	<ul style="list-style-type: none"> <li>• How to create and structure directories and files correctly (eg importing, copying, transferring, exporting, deleting, backing up and saving files, version control).</li> <li>• The different types of storage media that can be used to save program files.</li> <li>• How to save the completed programs in the appropriate format.</li> <li>• How to backup completed or edited programs, and the implications if this is not carried out effectively.</li> </ul>



## Performance outcomes

On successful completion of this unit learners will be able to:

Performance outcome 1:	Understand the role of PLCs in engineering systems and subsystems.
Performance outcome 2:	Understand the principles of computer programming.
Performance outcome 3:	Understand the basic operation of a PLC and its connectivity.
Performance outcome 4:	Design computer programs for use in engineering.

## Grading criteria

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
<b>PO1</b> Understand the role of PLCs in engineering systems and subsystems	<b>P1</b> <b>Research</b> the historical development of PLCs.		
	<b>P2</b> List the advantages and disadvantages of using PLCs in engineering.		
	<b>P3</b> Describe the application of PLCs in <b>three</b> organisations.	<b>M1</b> Compare and contrast the use of PLCs in given applications against the use of non-PLC methods.	<b>D1</b> Evaluate the limitations of current PLCs and the effects these could have on engineering practice.
<b>PO2</b> Understand the principles of computer programming	<b>P4</b> Identify the main programming languages that are used offline to program PLCs.	<b>M2</b> Select and justify a programming language to be used for a given purpose.	
	<b>P5</b> Describe the benefits of using a modular approach to programming.		



Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P6</b> Demonstrate through programming the use of PLC numbering systems (binary, octal, decimal, hexadecimal and binary coded decimal).		
	<b>P7</b> Demonstrate, through programming, different programming codes used to identify factors (eg safety interlocks/ guards and sensor inputs, actuator and other output process management and auxiliary functions).	<b>M3</b> Explain the way in which I/O is achieved in PLC programs.	<b>D2</b> Explain how validation and error checking will be used in the programming of a PLC.
	<b>P8</b> Demonstrate the use of And, Or and Not logic gates in PLCs.		
<b>PO3</b> <b>Understand the basic operation of a PLC and its connectivity</b>	<b>P9</b> Describe the way in which the processor in a PLC processes a program. Include how the processor handles I/O.		
	<b>P10</b> Describe the basic configuration of a PLC controlled system for a given application.	<b>M4</b> Select and justify the input/output devices to be used for a given purpose.	<b>D3</b> Explain the limitations of the PLC system being used (in relation to the intended purpose).
	<b>P11</b> Carry out checks to prepare a PLC machine for use including consideration of health and safety.		

Performance outcomes	Pass	Merit	Distinction
	<b>To achieve a pass the learner must evidence that they can:</b>	<b>In addition to the pass criteria, to achieve a merit the evidence must show the learner can:</b>	<b>In addition to fulfilling the pass and merit criteria, to achieve a distinction the evidence must show that the learner can:</b>
	<b>P12</b> Outline the relevant system maintenance and fault-finding techniques for a PLC machine.	<b>M5</b> Explain (with examples) the difference between preventative and routine maintenance in the context of PLCs.	
<b>P04</b> <b>Design computer programs for use in engineering</b>	<b>P13</b> Gather information from relevant sources to produce a PLC program for process control.	<b>M6</b> Explain which factors influenced the design of the PLC program.	
	<b>P14</b> Produce a PLC program design to solve a given problem identifying: <ul style="list-style-type: none"> <li>inputs, processes and outputs</li> <li>modules, subroutines and parameter passing relevant to the intended solution.</li> </ul>	<b>M7</b> Explain how the PLC program avoids unnecessary operations.	
	<b>P15</b> Carry out testing and simulation of a PLC program to demonstrate how it will achieve the desired outcome.	<b>M8</b> Identify program adjustments to reflect testing and potential for modification.	<b>D4</b> Evaluate a given PLC controlled system. Make reference to how the final PLC program satisfies the required outcomes established at the beginning of the process.
	<b>P16</b> Store the program and all related information correctly.		

## Assessment amplification

This section provides amplification of what is specifically required or exemplification of the responses learners are expected to provide.

Learners will be presented with an opportunity to demonstrate the transferable skill of research when completing P1.

Evidence of performance outcomes can be collected from a variety of sources such as assignments, practical activities, written reports and witness statements/observation records, though this module lends itself to the use of an extensive project that can encompass many of the outcomes.

The pass grade indicates the minimum level of performance required by the learners. Assessment must cover all of the performance outcomes. Achievement of a merit or distinction grade will require learners to submit work that demonstrates additional depth and breadth in the subject being assessed.

## P01 Understand the role of programmable logic controllers in engineering systems and subsystems

To achieve **P1** the learners need to research the use of PLCs since their introduction to the current time. It will require the learner to research the development of PLCs technology and application.

It is necessary for the learner to understand the influences on the development of PLCs, such as the miniaturisation of electronics, and to understand why PLCs are used instead of PCs. This is a natural introduction to PLCs and should be treated as an introduction to the unit.

To achieve **P2** the learner needs to appraise the application of PLCs and to demonstrate an understanding of where PLCs are a good solution and where they may not be the best solution, essentially to develop an understanding in the learner of where to utilise PLCs by producing a list of advantages and disadvantages.

To achieve **P3** learners will need to describe the application of PLCs across three different organisations to demonstrate breadth of knowledge. Learners need to understand that PLCs offer a customised solution to a problem. Learners will also need to understand the wide range of tasks that a PLC can perform and to understand their ability to control many other types of hardware. The description needs to include what the PLCs control and at least one application must be a machine application.

To achieve **M1** learners will need to compare and contrast current applications of PLCs with a non-PLC solution. This is meant to develop an understanding of why PLCs are used rather than other potential solutions.

## P02 Understand the principles of computer programming

To achieve **P4** learners will need to identify the main programming languages that are used offline to program PLCs.

To achieve **P5** learners will need to explain the benefits of a modular approach to programming. This could be either through a report of a wide range of applications or related to a specific stated application.

To achieve **P6** learners will need to provide copies of programs demonstrating the use of each numbering system.

To achieve **P7** learners will need to provide copies of (one or more) programs annotated to identify the different programming codes.

To achieve **P8** learners will need to provide copies of programs annotated to identify the use of logic gates.

To achieve **M2** learners will need to be provided with one or more specific applications. They should identify an appropriate programming language to use and provide reasons for its selection. This could be the same application as used for P5.

To achieve **M3** learners will need to provide a copy of a program annotated to explain the way in which I/O is achieved. This could be one of the programs used for P6, P7 or P8.

To achieve **D2** learners could produce either a report explaining validation and error checking in general terms, or an annotated copy of a program explaining how validation and error checking is used in a specific application. This could be one of the programs used for P6, P7, P8 or M3.

### P03 Understand the basic operation of a PLC and its connectivity

To achieve **P9** learners could produce either a report explaining in general terms, or an annotated copy of a program explaining how the processor in a PLC processes a program and handles I/O.

To achieve **P10** learners will need to understand how a PLC system is set up in order to perform a given task. This needs to include checking that all equipment is correctly connected and the correct start-up procedures to be used.

To achieve **P11** learners need to have an understanding of the health and safety issues related to the use of PLCs and also to demonstrate that they can develop strategies to militate against these issues. Health and safety refers to the safe use of PLCs and the potential risks from not configuring the system correctly.

For **P12** learners could provide a report outlining the requirements for an identified machine.

To achieve **M4** learners will need to be provided with one or more specific applications. They should identify appropriate devices to be used. This could be the same application as for P10.

For **M5** the evidence could be presented in the form of a series of photographs or video with a summary paragraph.

To achieve **D3** learners will need to be provided with one or more specific applications. They could explain the limitations either as a written statement or as annotations on a program. This could be the same application as for P10.

### P04 Evaluate and optimize control systems

For **P13** relevant sources could include data from drawings, computer models, BS or ISO standards.

To achieve **P14** learners will need to produce a design specification for a given project. This should be produced from an analysis of the client's desired outcomes. Learners should appreciate that their design solution needs to be approved by the client before they start to program.

For **P15** learners will need to provide a record of testing a PLC program. This could be evidenced through screen captures, video or a witness statement.

For **P16** learners will need to store a PLC program correctly. This could be evidenced through screen captures or a witness statement.

For **M6** learners will need to be provided with a specific application. This could be the same application as for P13 and P14. Evidence could be provided through a written statement or as annotations on the program.

For **M7** and **M8** evidence could be annotations on the program. This could be the same application as for P13 and P14.

For **D4** learners could produce either a report or a video with commentary.

## Synoptic assessment

This unit would logically be taught after Units 1, 2, 3, 4, 5 and 7 (or concurrently with Units 3 and 7) and there are opportunities for learners to demonstrate synoptic knowledge and learning from those other units in their evidence for this unit.

The amplification below identifies where the centre should consider synoptic assessment and where learning from other units can be assessed within this unit.

### P01 Understand the role of programmable logic controllers in engineering systems and subsystems

When assessing the advantages and disadvantages of PLCs in P2, M2 and D1, you should see learners' broader knowledge and understanding of the commercial and economic context of engineering systems applied from Unit 2 Mechanical systems PO2. They should also apply their knowledge of the wide ranging external considerations from Unit 6 Mechatronic project management PO2 P7 and M5 and their specific knowledge of microcontrollers from Unit 7 Mechatronic control systems PO3 P10, M6 and M7.

The learning of applications of PLCs in P3 could be taught concurrently with different examples of mechatronic control systems in Unit 7 Mechatronic control systems PO1 P1.

### P02 Understand the principles of computer programming

When selecting programming languages in P4 and M2, demonstrating the use of programming codes in P7, logic gates in P8 and explaining the way in which I/O is achieved, learners should build on their knowledge from Unit 5 Production and manufacturing PO2 P4 and M4.

The use of different numbering systems in P6 should apply learners' knowledge of using mathematics to solve engineering problems from Unit 3 Mathematics for engineers AO1.

When assessing the validation and error checking of PLC programs in D2, you should see knowledge and skills for programming CNC equipment applied from Unit 5 Production and manufacturing PO2 M4.

### P03 Understand the basic operation of a PLC and its connectivity

When explaining how a microcontroller handles inputs and outputs in P9, M4 and D3, learners should apply their knowledge of analogue and digital signals and calculating values in electronic circuits from Unit 1 Materials technology and science AO4, and the operating characteristics of electrical drives from Unit 2 Mechanical systems PO2. These will also facilitate learners to apply their knowledge from Unit 3 Mathematics for engineers AO1 and AO3 to determine the operating characteristics of the system.

When considering safe operating practices in P11, learners should apply their understanding from Unit 2 Mechanical systems PO3, and Unit 5 Production and manufacturing PO4 P9.

When assessing the maintenance requirements identified in P12 and M5, you should see knowledge of requirements at the design stage applied from Unit 4 Engineering design PO1. Where this is based on graphical processes such as condition monitoring, this should apply understanding from Unit 2 Mechanical systems PO3 and mathematical skills developed in Unit 3 Mathematics for engineers AO1, AO5 and AO6.

When carrying out fault-finding in P12, learners should apply their knowledge of fault-finding techniques from Unit 2 Mechanical systems PO3 and testing from Unit 5 Production and manufacturing PO2 M4.

## PO4 Design computer programs for use in engineering

When assessing the gathering of information to produce a PLC program in P13, you should see learning and skills applied from Unit 5 Production and manufacturing PO4 P8.

When calculating movement requirements such as tool paths (for example, by vector addition and subtraction) or converting between polar and cartesian coordinates as part of P13 or P14, learners should apply learning from mathematical methods of addressing practical engineering problems and the use of trigonometry and coordinate geometry in Unit 3 Mathematics for engineers AO1 and AO4.

When producing or modifying PLC programs in P14, M6, M7 and M8, learners should apply knowledge and skills developed for programming CNC equipment in Unit 5 Production and manufacturing PO2 P4.

When assessing the testing and simulation use of PLC programs in P15, you should see knowledge and skills developed for programming CNC equipment applied from Unit 5 Production and manufacturing PO2 M4 and D3.

When assessing the evaluation of a PLC controlled system in D4, you should see evaluation skills applied from Unit 5 Production and manufacturing PO2 D3 and PO5 D4. They should also apply learning from Unit 3 Mathematics for engineers AO2 to quantify performance.

## Delivery guidance

The performance outcomes should be, wherever possible, delivered through the practical application of PLC programming linked to hardware applications and utilising the software development process. The emphasis must be on the practical application of the knowledge gained in the unit and on the development within the learner to program solutions from the relatively simple to the more complicated. It is expected that much of the development can be undertaken through simulation software but it is necessary for the learners to be exposed to a total solution utilising several PLCs and many I/Os.

The performance outcomes may be taken in any order, however, it would seem appropriate to follow the order as presented.

**Performance outcome 1** is a review of the use of PLCs since their introduction to the current time. It will require the learner to research the development of PLCs and may require access to someone in industry who has had experience of using them.

It is necessary to understand the influences on the development of PLCs, such as the miniaturisation of electronics, and to understand why PLCs are used instead of PCs. This is a natural introduction to PLCs and should be treated as an introduction to the unit.

The outcome also develops the learners' knowledge concerning the application of PLC across the whole breadth and width of industry. Learners need to understand that PLCs offer a customised solution to a problem. Learners will also need to understand the wide range of tasks that a PLC can perform and to understand their ability to control many other types of hardware.

**Performance outcome 2** develops the learners' knowledge of programming and programming techniques. This is a practical outcome and should utilise simulation software whilst skills are being developed but it should culminate in the programming of an industrial application which will be simulated but will include several PLCs linked to hardware that are performing a particular task. It may be possible to expose the candidates to more than one of these simulations.

**Performance outcome 3** focuses the learners on how the PLC interfaces with the other items of hardware in order to perform a design solution. The learner would need to be exposed to an industrial application of PLCs through industrial visits and industrial speakers.

**Performance outcome 4** focuses the learners on how to develop a design solution through appropriate steps and also how the designer needs to communicate properly with the client and having the client's approval to pass from one stage to the next. This is meant to emphasize to the learner that to simply start programming without due consideration is not the best way in which they develop a robust design solution and will waste important time.

## Essential resources

Centres will need access to PLC based equipment and simulation software located in a laboratory environment. Access to industrial applications of PLCs and utilising local companies to include visiting speakers with PLC experience, will also be essential. There will need to be a wide range of components and test equipment available. Reference books, video/DVD and access to the internet should be available.

## Employer engagement guidance

Liaison with local industry is to be strongly recommended. Seek out their assistance in providing work placements or visits, invite specialist personnel to visit the centre and give talks on various aspects of their company relating to control systems. They can also be a valuable resource for sample systems both working and damaged, each of which can be used for training purposes.

Centres should also be in contact with professional institutions most of which have education officers who can marshal a team of volunteers to give talks, demonstrations and arrange visits.

A recent report, published in January 2014 and commissioned by CfBT, on employer engagement may be found on their website at: [cfbt.com/en-GB/Research/.../2014/r-employer-engagement-2014](http://cfbt.com/en-GB/Research/.../2014/r-employer-engagement-2014)

## Useful links and resources

- Elvin Pérez Adrover, *Introduction to PLCs: A beginner's guide to Programmable Logic Controllers*, ISBN-10: 061565438X, 2012
- Bolton, *Programmable Logic Controllers*, ISBN-10: 1856177513, Newnes, 2005.



# 13 Externally set and marked examinations

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## 13.1 Introduction

The Foundation Technical Level (360 GLH) in Engineering (TVQ01019) qualification unit F/506/5952 (Materials technology and science) is assessed via an externally set and marked AQA examination.

For the Technical Level (720 GLH) in Engineering: Mechatronic Engineering (TVQ01016) qualification units F/506/5952 (Materials technology and science) and J/506/5953 (Mathematics for engineers) are assessed via an externally set and marked AQA examination.

External examinations are set by AQA (sometimes in collaboration with an employer or a professional body) and are sat by learners in a controlled examination environment, at a pre-set time and date and marked by AQA.

Examinations are available for externally assessed units in January and June and entries must be made in accordance with AQA's procedures.

Further information on how to make entries for examinations can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications*.



## 13.2 Examination format and structure

Unit title	F/506/5952 – Materials technology and science
Exam sessions	January and June
Duration	1 hour and 45 minutes
Type of exam	<p>Written exam</p> <p>This unit will be assessed through an external examination set and marked by AQA. The examination will take place under controlled examination conditions and the date will be published at the start of each academic year.</p> <p>Learners will be allowed to use a non-programmable scientific calculator in the examination. Please note that, in line with typical practice within the engineering industry, learners are not expected to be able to recall formulae for use when answering questions that require mathematical calculations. They are expected to be able to select, manipulate (if required) and apply appropriate equations from provided formulae sheets.</p> <p>The examination will consist of a written paper with two sections, A and B. Learners will have to complete both sections and there will be no optional questions within either section.</p> <p>Section A will be worth 50 marks and consist of relatively short questions based on the whole of the specification for this unit. The learners will be required to answer all of the questions in Section A.</p> <p>Section B will be worth 30 marks and will include both short and longer answer questions worth up to 10 marks each. Each of these will focus on a practical engineering context. The questions in Section B will not necessarily cover the whole of the specification for this unit at each assessment. Learners will be required to answer all of the questions in Section B.</p> <p>AQA will ensure that the full content of the unit is covered equally over the life of the qualification.</p>
Number of marks	80
Weighting of unit	<p>25 % of qualification TVQ01019 (360 GLH)</p> <p>12.5 % of qualification TVQ01016 (720 GLH)</p>

Unit title	J/506/5953 – Mathematics for engineers
Exam sessions	January and June
Duration	1 hour and 45 minutes
Type of exam	<p>Written exam</p> <p>This unit will be assessed through an external examination set and marked by AQA. The examination will take place under controlled examination conditions and the date will be published at the start of each academic year.</p> <p>Learners will be allowed to use a non-programmable scientific calculator in the examination. Please note that, in line with typical practice within the engineering industry, learners are not expected to be able to recall formulae for use when answering questions that require mathematical calculations. They are expected to be able to select, manipulate (if required) and apply appropriate equations from provided formulae sheets.</p> <p>The examination will consist of a written paper with two sections, A and B. Learners will have to complete both sections and there will be no optional questions within either section.</p> <p>Section A will be worth 50 marks and consist of relatively short questions based on the whole of the specification for this unit. The learners will be required to answer all of the questions in Section A.</p> <p>Section B will be worth 30 marks and will include both short and longer answer questions worth up to 10 marks each. Each of these will focus on a practical engineering context. The questions in Section B will not necessarily cover the whole of the specification for this unit at each assessment. Learners will be required to answer all of the questions in Section B.</p> <p>AQA will ensure that the full content of the unit is covered equally over the life of the qualification.</p>
Number of marks	80
Weighting of unit	12.5 % of qualification TVQ01016

### 13.3 Reasonable adjustments and special considerations

Information on the reasonable adjustments allowed for the external examinations within this qualification can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications*.

### 13.4 Availability of past examination papers

Sample and past examination papers for this qualification are available from AQA.

# 14 Externally set and marked assignments

Unit H/507/6524 (Mechanical systems) of this qualification is assessed via an externally set and marked AQA assignment.

External assignments are set by AQA (sometimes in collaboration with an employer or a professional body), and are sat by learners in a supervised environment and marked by AQA.

In exceptional circumstances, centres may wish to modify the task sheet to take account of the conditions and equipment available in their centre or to reflect the specific employer/industrial focus they are using. Any modification must be discussed and agreed, in writing, with AQA before learners undertake the task. Any requests should be sent to [techlevels@aqa.org.uk](mailto:techlevels@aqa.org.uk). A copy of the correspondence giving authorisation for the change will then be sent to the AQA examiner.

Further information on how to make entries for external assignments can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications* at [aqa.org.uk](http://aqa.org.uk)

## 14.1 Assignment format and structure

There are two assignments for unit H/507/6524 (Mechanical systems) in each academic year. Learners can choose which of the assignments they wish to complete.

Materials for both assignments are released to centres on a specified date each year. This date can be obtained from the AQA website [aqa.org.uk](http://aqa.org.uk)

There are two windows for assessment each year when centres must submit their learners' completed external assignments to AQA for marking. The dates of these windows can be obtained from the AQA website.

Learners must undertake their external assignment tasks individually and under supervised conditions. The *Guidance notes for tutors* and the *Assignment brief* provide specific instructions on the way in which the assignment tasks should be delivered.

## 14.2 Preparation

The assignment should only be undertaken after learners have acquired the necessary skills and after teaching for the appropriate sections of the specification has taken place. Learners should also be familiar with any apparatus, equipment or materials they will need to use.

Centres should organise an appropriate approach to the delivery of the assignment that takes into account when the assignment becomes available and when completed learner work is required by AQA for submission.

A centre may carry out the tasks, using similar apparatus, equipment and materials as the learner, in order to obtain centre results. This must not be done in the presence of the learners and the evidence produced must not be provided to the learners as an exemplar.

## 14.3 Risk assessment and risk management

Risk assessment and risk management are the responsibility of the centre.

## 14.4 Carrying out the assessment

Learners are expected to work individually.

Unless specific guidance to the contrary is made in the *Assignment brief*, centres should not give any advice to learners regarding completing the assignment. The centre may only give advice or guidance to learners about the way they are conducting practical work if it is to prevent personal injury or damage to equipment or apparatus.

Where resources mean that equipment has to be shared, centres should ensure that the learners complete the task individually (eg by taking turns with the equipment to produce their evidence).

Details of any supporting documents, materials or electronic devices that can be used by learners during the assessment will be provided within the *Guidance notes for tutors* and the *Assignment brief*. The circumstances in which learners are permitted to undertake research will also be specified within the *Guidance notes for tutors* and the *Assignment brief*.

The ability to present evidence in an appropriate format will be an important part of the assessment. The centre must not provide learners with blank templates to complete or direct learners in designing and completing their own work.

Learners must work individually and under controlled conditions. Each task within the assignment should normally be completed in continual sessions. Centres can judge how many sessions are appropriate for their own learners.

As a guide, the assignment should be completed in approximately 20 hours. The brief indicates how much time should be allocated to each task however centres can adjust these as appropriate for their learners. Centres do not need to record the hours spent on the assignment however you should encourage learners not to exceed the overall time or the time for each task.

At the start of each session, the centres should give each learner a copy of the assignment, together with the appropriate apparatus and materials to carry out the task.

## 14.5 Learner absence

If a learner is absent for a part of the assignment then they should be given the opportunity to undertake the part of the assignment missed before they move on to the next stage. This may be with another group or at a different time.

## 14.6 Storage of materials

Materials for each assignment must be kept unopened and in secure storage until the date upon which the centre wishes to commence work on the assignment with learners.

Secure storage is defined as a securely locked cabinet or cupboard.

Whilst undertaking assignment tasks, at the end of each session, the centre must collect the learners' work and keep it securely until the next session. Learners must not take any assessment materials away at the end of a session. Specific rules relating to the security of assessment can be found in the *Guidance notes for tutors*.

Further guidance on secure storage can be found in the *JCQ Instructions for Conducting Examinations* document at [jcq.org.uk/exams-office/ice---instructions-for-conducting-examinations](http://jcq.org.uk/exams-office/ice---instructions-for-conducting-examinations)

Where learners' work is in an electronic format, centres must take steps to ensure that they meet the requirements for secure storage described above. This may involve collecting USB memory sticks for secure storage between sessions or restricting learners' access to specific areas of the centre's IT network.

As a general rule, learners should use the IT facilities provided by their centre. Where learners wish to/are required to use their own equipment, then the centre is responsible for establishing and implementing a procedure to ensure compliance with the requirements for secure storage described above.

## 14.7 Submission of learner work

Deadlines for submission of assignments will be provided on the AQA website [aqa.org.uk](http://aqa.org.uk)

Details of submission arrangements can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications* at [aqa.org.uk](http://aqa.org.uk)

To ensure that the external assignment has been completed appropriately, learners and tutors are required to confirm before all learner work is sent to AQA for marking that each of the learners has undertaken the assessment appropriately and in accordance with the rules.

## 14.8 Redrafting or resubmission of learner work

Learners may only make one attempt at each assignment and redrafting is not allowed at any stage. Learners who wish to re-sit a unit assessment must attempt a different assignment.

## 14.9 Suspected malpractice or maladministration

Where centres suspect that the work produced by the learner is not their own, then this could potentially be malpractice. Further guidance on dealing with malpractice can be found in the JCQ document *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* – [jcq.org.uk/exams-office/malpractice](http://jcq.org.uk/exams-office/malpractice) and in the *AQA Centre Administration Guide for Technical and Vocational Qualifications* at [aqa.org.uk](http://aqa.org.uk)

# 15 External quality assurance

## 15.1 Overview

AQA's approach to quality assurance for this qualification is described within each unit specification.

External quality assurance for Tech-levels takes the form of verification and is concerned with maintaining the quality of assessment and checking that the assessment process has been undertaken appropriately by centre staff. It focuses on auditing the whole process and enables the head of centre, and all individuals involved in the assessment process, to understand what is required by them.

## 15.2 Quality assurance visits

When a learner is registered or a centre wants to submit work, this triggers a verification visit from an AQA external quality assurer (EQA).

Once a centre has registered learners, these visits will occur, as a minimum, every six months and will be face-to-face at a centre.

Our EQAs offer advice and guidance on any aspect of quality assurance in between formal visits, via telephone or email, and additional visits can be arranged.

These meetings will involve verifying that:

- all of the staff, resources, processes and procedures are still in place
- the centre is continuing to meet the approved centre criteria (those signed off during the initial centre approval visit)
- there is evidence of meaningful employer involvement in delivery.

A major part of the verification process is to check that the centre's policies and procedures (including internal standardisation minutes, record keeping, IQA/assessor records and materials) meet AQA's requirements and ensure valid and reliable assessment.

The EQA will look at a representative sample of learner work to verify that the results awarded by the centre are valid, as well as reviewing evidence of the activities that have been undertaken to standardise assessments.

These samples will be taken from different sites if the centre operates at more than one location, from different centre assessors or IQAs and at different stages of delivery – all samples will be selected by the EQA.

As part of the sample, the EQA will request examples of learner work at Pass, Merit and Distinction. This will also support the centre in their internal standardisation.

If centre assessment decisions are found to be inconsistent, adjustments can be made (at a learner and cohort level) or in more severe cases (where a fundamental inconsistency or non-compliance is identified), sanctions (from a Level 1 Action plan through to Level 4 Suspension of delivery) can be put in place.

## 15.3 Sanctions

Sanctions are used to help process improvement and are a way of protecting the validity of assessments or assessment decisions. We will only ever impose sanctions on a centre that are proportionate to the extent of the risk identified during the quality assurance process.

Sanctions can be applied at a learner, centre or centre staff level – and they can be at qualification or centre level and take the following form:

- Level 1: Action point in EQA report.
- Level 2: Suspension of direct claims status (where applicable).
- Level 3: Suspension of learner registration and/or certification.
- Level 4: Withdrawal of centre approval for a specific qualification.

Further information on levels and application of sanctions can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications*.

# 16 Internal assessment and quality assurance

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## 16.1 Overview

The Foundation Technical Level (360 GLH) in Engineering (TVQ01019) qualification units D/506/6008 (Engineering design) and H/506/6009 (Production and manufacturing) are internally assessed by the centre.

The Technical Level (720 GLH) in Engineering: Mechatronic Engineering (TVQ01016) qualification units D/506/6008 (Engineering design), H/506/6009 (Production and manufacturing), R/506/6023 (Mechatronic project management), Y/506/6024 (Mechatronic control systems) and D/506/6025 (Programming for engineers) are internally assessed by the centre.

All assessment decisions that are made internally within a centre are externally quality assured by AQA.

AQA has worked with employers and professional bodies to produce guidance on what is the most appropriate form of assessment or evidence gathering for all internal centre assessment.

The most appropriate method of assessment (or evidence gathering) is detailed against each unit. Should a centre wish to use an alternative method of assessment to that detailed, then justification must be provided during AQA quality assurance visits to the centre.

This justification needs to lay out why the centre feels their approach to assessment is more appropriate, efficient or relevant to the learner and/or subject and should be provided in writing to the AQA external quality assurer.

Centres should tailor the assessment to suit the needs of the learner, and internal assessments can take place at a time to suit the centre or learner.

Centres should take a best practice approach with learners being assessed through real life or work-based activity to generate the required evidence (see Section 8.1 Meaningful employer involvement).

## 16.2 Role of the assessor

The role of the assessor is to:

- carry out initial assessments of learners to identify their current level of skills, knowledge and understanding, and any training or development needs
- review the evidence presented against the requirements of the qualification, to make a judgement on the overall competence of learners
- provide feedback to learners on their performance and progress. This feedback needs to give learners a clear idea of the quality of the work produced, where further evidence is required and how best to obtain this.



## 16.3 Assessor qualifications and experience

In order to assess learners working towards this qualification, assessors must:

- have appropriate knowledge, understanding and skills relevant to the units within this qualification
- or
- have experience as a practitioner and/or teaching and training with significant experience of creating programmes of study in relevant subject areas.

## 16.4 Applying portfolio assessment criteria

When assessing learners' work, the centre should consider the level of attainment in four broad areas:

- 1 the level of independence and originality
- 2 the depth and breadth of understanding
- 3 the level of evaluation and analysis
- 4 the level of knowledge, skills or competency demonstrated.

## 16.5 Authentication of learner work

The centre must be confident that a learner's work is their own. You must inform your learners that to present material copied directly from books or other sources such as the internet, without acknowledgement, will be regarded as deliberate deception. This also includes original ideas, as well as the actual words or artefacts produced by someone else.

Learners' work for assessment must be undertaken under conditions that allow the centre to authenticate the work. If some work is done unsupervised, then the centre must be confident that the learners' work can be authenticated with confidence – eg being sufficiently aware of an individual learner's standard and level of work to appreciate if the evidence submitted is beyond the level of the learner.

The learner is required to sign a declaration that the work submitted for assessment is their own. The centre will also countersign this declaration that the work was carried out under any specified conditions – recording details of any additional assistance. This must be provided with the learner's work for external quality assurance purposes.

Any assistance given to an individual learner beyond that given to the group as a whole, even if within the parameters of the specification, must also be recorded.

If some work is done as a part of a team, the centre must be confident that the learner's contribution to that team activity can be clearly identified and authenticated.

## 16.6 Tutor assistance and feedback

Whilst learners are undertaking assignment tasks, tutors must ensure that any assistance given, or offered as a result of a learner's question and/or request for help, does not compromise the learner's ability to independently perform the task in hand.

During assessment, tutors can give general feedback and support to learners, most notably, on the following:

- development of the required knowledge and skills underpinning the assignment at hand
- confirmation of the assessment criteria being assessed
- clarification of the requirements of the *Assignment brief*
- identification of assignment deadlines.

Tutors, however, must not assist learners directly and specifically with assignment tasks.

Tutors are not permitted to provide 'formative' feedback on learner's work, ie feedback, prior to submission for marking, on an assignment/task that will enable the learner to amend the assignment/task to improve it.

Once learner work has been submitted for marking, then tutors must give clear and constructive feedback on the criteria successfully achieved by the learner. Tutors should also provide justification and explanation of their assessment decisions. Where a learner has not achieved the performance criteria targeted by an assignment, then feedback should not provide explicit instructions on how the learner can improve their work to achieve the outstanding criteria. This is to ensure that the learner is not assisted in the event that their work is considered for resubmission.

## 16.7 Research and references

Where learners are required to undertake research towards the completion of a task, they should reference their research results in a way that is informative, clear and consistent throughout their work. We do not prescribe a specific way to organise references, but we expect tutors to discuss this with learners and identify a 'house style' that learners are then expected to use. Learners may include a bibliography of relevant sources on larger assignments where there has been significant research and there is value in recording all sources fully.

## 16.8 Role of the internal quality assurer

An internal quality assurer (IQA) must be appointed to ensure the quality and consistency of assessments within the centre. Each assessor's work must be checked and confirmed by an internal quality assurer.

The IQA must observe assessors carrying out assessments, review assessment decisions from the evidence provided and hold standardisation meetings with the assessment team to ensure consistency in the use of documentation and interpretation of the qualification requirements.

All assessment decisions made within a centre must be standardised to ensure that all learners' work has been assessed to the same standard and is fair, valid and reliable.

Evidence of all standardisation activity should be retained by the centre and could take the form of, for example, records of training or feedback provided to assessors, minutes of meetings or notes of discussions.

Our external quality assurers (EQAs) will always be happy to provide guidance and assistance on best practice.

Internal standardisation activity may involve:

- all assessors marking trial pieces of work and identifying differences in marking standards
- discussing any differences in marking at a training meeting for all assessors
- cross-moderation of work between assessors.

## 16.9 Internal quality assurer qualifications and experience

In order to internally quality assure the assessment of learners working towards this qualification, IQAs must:

- have appropriate knowledge, understanding and skills relevant to the units within this qualification
- or
- have experience as a practitioner and/or teaching and training with significant experience of creating programmes of study in relevant subject areas.

### 16.10 Record keeping

The centre must be able to produce records that show:

- the assessor and IQA allocated to each learner
- the evidence assessed
- the dates of assessment and IQA
- details of internal standardisation activities of the assessor – (what, when and by whom)
- the grade awarded and rationale for this.

# 17 Resits, resubmissions and retakes

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## 17.1 Note on terminology

**Resits** refer to learners taking further attempts at an examined/externally assessed unit.

**Resubmissions** refer to learners undertaking a second attempt at an internally assessed unit task/assignment prior to external quality assurance.

**Retakes** refer to learners undertaking a second attempt at an internally assessed unit after external quality assurance.

## 17.2 Rules on resits, resubmissions and retakes

Resits and retakes are permitted where a learner has either failed the requirements of the unit, or where they wish to improve on a grade awarded.

For certification purposes, AQA will recognise the best achievement by the learner and not the most recent.

### Resitting an exam or external assessment

The learner is permitted **three** attempts (one initial and two resits) in relation to each examined/externally assessed unit of the specification.

Learners who have been awarded the Foundation qualification and have progressed to the full Technical Level are allowed to use the resit opportunities to go back and improve the grade achieved in the external assessment. Any improvement cannot be used to upgrade and reclaim the previously awarded Foundation qualification.

### Resubmitting internal assessments

The learner is permitted **one** resubmission in relation to each internally assessed unit of the qualification, but only when the tutor believes the learner can achieve the outstanding criteria without further guidance. Any resubmission of work must be undertaken prior to external moderation.

### Retaking internal assessments

The learner is permitted **one** retake in relation to each internally assessed unit of the qualification. This could mean the learner doing the entire unit work again, or simply correcting a task/assignment before the unit is again submitted for external moderation by AQA. With a retake, learners are not allowed a resubmission opportunity.

Any retake and/or resubmission of work must be completed within a defined and reasonable period of time following learner feedback of the initial assessment. Any work provided as evidence must be authenticated by the learner as their own.

# 18 Grading

## 18.1 Overview

Performance in all units is graded at Pass, Merit or Distinction. These unit grades are then converted into points and added together to determine the overall grade for the qualification.

The overall Foundation Technical Level in Engineering (TVQ01019) qualification is graded as P, M, D, D\*.

The overall Technical Level in Engineering: Mechatronic Engineering (TVQ01016) qualification is graded as PP, MP, MM, DM, DD, D\*D, D\*D\*.

## 18.2 Internally assessed units

Centres must ensure that all assessment criteria in the unit are covered during the teaching and learning process so that learners can meet the requirements. Work should be assessed against the grading criteria provided within each unit.

- To achieve a Pass, a learner must have satisfied all Pass criteria.
- To achieve a Merit, a learner must achieve all of the Pass and all of the Merit criteria.
- To achieve a Distinction, a learner must achieve all of the Pass, Merit and Distinction criteria.

## 18.3 Externally assessed (examined) units

These units are assessed by AQA using a marks-based scheme. After the assessment has taken place and been marked, the grade boundaries are set by AQA. These grade boundaries are based on the level of demand of the assessment and learners' performance – all learners that took the assessment, not just those in your centre.

When the assessment results are shared with the centre, AQA will report on the grade boundaries.

**Note:** These grade boundaries may change for each assessment window according to the demand of the assessment – this is important to maintain standards across each window.

Learners' grades are converted into points.

## 18.4 Points per grade – unit level

Table 1 shows the points for each grade at a unit level.

Table 1: Points per grade

Grade	Internally/centre assessed unit
Pass	36
Merit	54
Distinction	72

## 18.5 Final grade for overall qualification

The final grade for the overall qualification will be calculated by adding together the points achieved for each unit.

The total possible number of points that can be achieved for the Foundation Technical Level (360 GLH) in Engineering is 288.

The total possible number of points that can be achieved for the Technical Level (720 GLH) in Engineering: Mechatronic Engineering is 576.

### Points for overall qualification grade

**Table 2: Foundation Technical Level (360 GLH) in Engineering (TVQ01019)**

Grade	Points boundary
P	144
M	198
D	252
D*	270

**Table 3: Technical Level (720 GLH) in Engineering: Mechatronic Engineering (TVQ01016)**

Grade	Points boundary
PP	288
MP	360
MM	396
DM	468
DD	504
D*D	522
D*D*	540

## 18.6 The 'Near Pass' rule

A near pass will be applied to an **externally assessed unit or external assignment** for those learners who may fall just short of a pass grade. The unit grade will still be reported as a grade U, since the learner will not have performed to the minimum standard required for a Pass grade, but will qualify as a near pass for the purposes of determining the overall qualification grade.

The actual mark required to achieve the 'near pass' grade on an examined unit will change from year to year, depending on the grade boundaries that have been set. For an external assignment a learner will achieve a 'near pass' if they satisfy all but one of the Pass criteria for the unit. A learner will receive 27 points if they achieve a Near Pass.

A learner is allowed one Near Pass in an externally assessed unit or external assignment in a Foundation Technical Level or up to two Near Pass results (six or eight unit Technical Level) or up to three Near Pass results (12 unit Technical Level).

All other eligibility requirements for achieving the qualification will remain the same:

- the total points score is above the Pass threshold; **and**
- all other units are passed

# 19 Administration arrangements

Full details of all of the administration arrangements relating to AQA Tech-levels can be found in the *AQA Centre Administration Guide for Technical and Vocational Qualifications*, including:

- how to apply for centre approval
- registration of learners
- dealing with recognition of prior learning (RPL)
- how to make examination entries
- dealing with missed examination dates
- examination invigilation arrangements
- how to make claims for certificates
- how to appeal against an assessment, IQA or EQA decision
- retention of learner work and assessment/IQA records
- dealing with potential malpractice or maladministration.

Details of all AQA fees can be found on the AQA website at [aqa.org.uk](http://aqa.org.uk)

# 20 Appendix A: Transferable skills standards and guidance

## 20.1 Transferable skills – communication standards (oral)

Evidence must clearly show that the learner can:

<b>CO1</b>	Prepare a suitable presentation.	1.1 Research suitable topics for the presentation. 1.2 Research the most appropriate format for the presentation. 1.3 Plan the structure of the presentation. 1.4 Make use of any appropriate supporting materials and prepare any other resources needed for the presentation.
<b>CO2</b>	Use language, vocabulary, tone and style suited to the complexity of the topic and the context.	2.1 Use appropriate language and vocabulary. 2.2 Structure what is presented to help the audience follow the sequence of the main points and ideas. 2.3 Use tone and style of presentation appropriate to the audience and environment.
<b>CO3</b>	Use a variety of methods to engage the audience.	3.1 Provide examples to illustrate complex points. 3.2 Use relevant images from appropriate sources to illustrate key points. 3.3 Use at least one additional method to engage the audience.

### Required evidence<sup>6</sup>

- Learner preparation evidence (planning notes, research).
- Learner presentation including all support materials.
- Assessor observation record\*.

### Learner guidance

The learner should consider the purpose, topic and audience as follows:

- the presentation should be eight minutes long to allow the learner to demonstrate the appropriate skills
- the presentation must always be contextualised within the technical subject content, and should not be simulated
- an audience of at least two or three people which may or may not include peers.

<sup>6</sup> For evidence marked with an asterix (\*) recording documents are available for centres to use – please see [aqa.org.uk/tech-levels/transferable-skills](http://aqa.org.uk/tech-levels/transferable-skills)



## C01

There should be evidence showing that the learner has:

- researched the technical subject content of a complex matter
- selected information relevant to the purpose of the presentation
- planned how to structure the presentation
- planned to use a relevant image or images to illustrate key points of the presentation – that adds value to the overall presentation
- included one additional method to engage audience for example questioning, completion of hand-out, discussion etc.

## C02

Learners should:

- give a well-structured delivery and must clearly highlight the main points of their presentation using tone, gesture or expression
- use appropriate vocabulary suited to the audience and environment.

## C03

Learners must:

- give examples to explain ideas
- make effective use of an image or images and other support materials to engage the audience and to illustrate key points, for example through use of video clips, explanatory notes or other technically related activities.

## Tutor guidance

- Tutors should use an observation record to support their assessment.
- Tutors should ensure that those observing are familiar with the observation record content and purpose.
- The presentation may be delivered through spoken communication or using sign language.
- Tutors should look for fitness of purpose and styles of presentation. Brief notes may be used as a prompt, but learners should not rely on them entirely.

## 20.2 Transferable skills – communication standards (written)

Evidence must clearly show that the learner can:

<b>CW1</b>	Select appropriate formats for presenting information as a report.	1.1 Decide on the most appropriate format for the technical report. 1.2 Plan the structure of the technical report. 1.3 Make use of any appropriate supporting materials and prepare any other resources needed for the technical report.
<b>CW2</b>	Select and use an appropriate style and tone to suit their audience.	2.1 Use appropriate language and vocabulary. 2.2 Structure the technical report to help the audience follow the sequence of the main points and ideas. 2.3 Use tone and style appropriate to the intended recipient(s).
<b>CW3</b>	Organise material coherently, to suit the length, complexity and purpose of their technical report, proofread and where necessary, re-draft documents.	3.1 Spell, punctuate and use grammar accurately. 3.2 Make their meaning clear. 3.3 Use relevant images from appropriate sources to illustrate key points. 3.4 Proofread their technical report. 3.5 Obtain feedback and amend technical report accordingly.

### Evidence required<sup>7</sup>

- A learner technical report of at least 1,000 words excluding support materials.
- An assessor recording form\*.

### Learner guidance

The learner should:

- produce a technical report about a complex subject which must be at least 1,000 words long
- include subject matter, which may well have a number of strands that is challenging to the individual learner in terms of the ideas it presents.

<sup>7</sup> For evidence marked with an asterix (\*) recording documents are available for centres to use – please see [aqa.org.uk/tech-levels/transferable-skills](http://aqa.org.uk/tech-levels/transferable-skills)

## CW1

It is essential that learners know how to:

- organise their technical report
- link paragraphs in various ways
- use features, such as indentation and highlighting, to suit different types of documents.

## CW2

Learners should know how to:

- produce a technical report that takes account of the vocabulary, tone and techniques normally used when producing documents for particular purposes and different recipients
- write with confidence and with the appropriate degree of formality.

## CW3

In supporting key points:

- images that could be used include: graph, sketch, picture or material taken from a presentation
- learners should know how to check their work to ensure that spelling, punctuation and grammar are accurate
- learners should know how to write grammatically correct sentences, including correct use of a variety of verb tense, form and person (for example passive voice); spell accurately, complex, irregular and technical words and use punctuation effectively for example bullet points, semicolon, colon, apostrophes) to ensure their meaning is clear.

## Tutor guidance

For the technical report produced, assessors should look for evidence that the learner has:

- selected an appropriate format for report
- organised relevant information using a clear and coherent structure
- used technical vocabulary when appropriate
- ensured that text is legible with accurate use of spelling, grammar and punctuation.

The learner should not be penalised for one or two errors providing meaning is still clear.

## 20.3 Transferable skills – problem-solving standards

Evidence must clearly show that the learner can:

<b>PS1</b>	Identify a problem and the tools and techniques that could be used to explore the problem.	1.1 Identify, analyse and describe the problem. 1.2 Identify a variety of tools and techniques which could be used to explore the problem. 1.3 Plan how you will investigate the problem highlighting which tools and techniques will be used.
<b>PS2</b>	Implement both the plan to investigate the problem and the plan to solve the problem.	2.1 Implement the plan for investigating the problem and seek support and feedback from others as necessary. 2.2 Record and analyse the results of the investigation. 2.3 Identify the solution(s) to solve the problem. 2.4 Plan the steps to be taken in order to solve the problem, identifying any risks, and implement the solution.
<b>PS3</b>	Check if the problem has been resolved and review the approach to tackling problems.	3.1 Check whether the problem has been resolved/solved. 3.2 Analyse the results and draw conclusions on the success of the problem-solving process. 3.3 Review the approach to tackling/solving the problem, including whether other approaches might have proved more effective.

### Evidence required<sup>8</sup>

- Explore/plan\* – to be completed by the learner.
- Do\* – to be completed by the assessor.
- Review\* – to be completed by the assessor.

### Learner guidance

The learner must demonstrate:

- a systematic approach to tackling problems, including identifying which is the most appropriate method, then developing a plan and implementing it
- how they went about the problem-solving process.

Evidence should be on individual performance. A group approach to problem-solving does not allow learners to achieve specific elements of the standards.

Activities must always be in relation to the core subject content and should not be simulated.

Effective definition of the problem will help the learner tackle it systematically and produce valid evidence. Tutors may discuss with learners the most appropriate definition of the problem and what sort of results might be expected so the learner is clear on what would show that the problem had been solved.

<sup>8</sup> For evidence marked with an asterix (\*) recording documents are available for centres to use – please see [aqa.org.uk/tech-levels/transferable-skills](http://aqa.org.uk/tech-levels/transferable-skills)

## PS1

Learners should:

- recognise, identify and describe the main features of the problem
- identify how they will explore the problem and the tools and techniques they will use
- use a variety of methods for exploring the problem.

## PS2

Learners should:

- obtain approval to implement their plan from an appropriate person, which could be the tutor or supervisor
- make effective judgements, based on feedback and support available, when putting their plan into action
- check their plan regularly for progress and revise it accordingly.

## PS3

Learners should:

- use an appropriate method for checking if the problem has been solved. For example if a learner designed a procedure or process for improving a system that records information, they would need to test this out and report back on their findings
- know how to describe the results in detail and draw conclusions on the success of their problem-solving skills
- reflect back on the process considering areas such as:
  - did they spend enough time considering the features of the problem?
  - were they effective in planning action points to tackle the problem?
  - did they take a logical approach to checking if the problem had been solved/resolved?

In some circumstances, achievement of the standard may be possible even if the problem has not been solved or resolved, especially if factors were outside of their control, and the learner was able to demonstrate the process of tackling the problem.

## Tutor guidance

- Tutors should check problem-solving implementation planning.
- Tutors may be required to provide a witness statement in support of evidencing the processes.

## 20.4 Transferable skills – research standards

Evidence must clearly show that the learner can:

<b>R1</b>	Design a research study.	1.1 Identify possible topics for research. 1.2 Choose one topic, identifying appropriate objectives for detailed research, and plan how to carry out the research. 1.3 Select a variety of resources to gather relevant information and identify appropriate methods and techniques to carry out the research.
<b>R2</b>	Conduct data collection and analysis.	2.1 Collect data using the appropriate methods to test the hypotheses/theories. 2.2 Carry out an appropriate analysis of the data. 2.3 Draw appropriate conclusions that are supported by the evidence from the data analysis.
<b>R3</b>	Present findings of the research and evaluate the research activities.	3.1 Prepare and present results of research. 3.2 Present the information in a clear and appropriate format adapted to the needs of the audience. 3.3 Seek feedback and use it to support own evaluation of research skills.

### Required evidence<sup>9</sup>

- Plan\* – to be completed by the learner.
- Do\* – to be completed by the assessor.
- Review\* – to be completed by the assessor.
- Results of research.

### Learner guidance

The learner should demonstrate they can:

- identify clear and appropriate objectives for the research study
- plan and carry out research activities with the particular objectives in mind
- design their research study in a systematic way
- present their findings as well as evaluating their research skills and activities
- be clear about the objectives of the research study, for example to assess the positive and negative impact of digital photography on sports journalism to predict future trends
- identify sources, methods and strategies they plan to use to investigate the topic
- carry out the research within a clearly defined structure, with a measure of complexity that should be reflected in the breadth and nature of the research objectives
- undertake the analysis required to make the best use of information/data and the requirement to give a clear justification for their conclusions
- make different research methodologies.

Activities must always be contextualised within the core subject content, and should not be simulated.

<sup>9</sup> For evidence marked with an asterix (\*) recording documents are available for centres to use – please see [aqa.org.uk/tech-levels/transferable-skills](http://aqa.org.uk/tech-levels/transferable-skills)

## RS1

The learner should explore:

- a variety of possible topics to research and should spend time deciding on clear and measurable objectives when designing their research study
- objectives and discuss and agree them with a tutor or supervisor
- a wide variety of sources when gathering their information
- the use of at least three different types of resource
- one source that is primary (gathered by the learner), for example, interview, questionnaire, survey, rather than from secondary for example encyclopaedia, interpretations of original material.

The learner should produce a plan detailing how they will carry out the research.

## RS2

The learner should:

- keep a record of the sources used
- independently collect information including data
- analyse information collected and identify information and data most relevant to their research objectives.

## RS3

When presenting their findings, learners should:

- use a format that is most appropriate to the content in terms of audiences, subject matter and research objectives
- communicate research findings clearly
- seek feedback from appropriate people
- show how they have used this feedback to help evaluate their research skills
- evaluate their research activities addressing all aspects including identifying the research objectives, collecting and analysing data and/or information, and recording, presenting and explaining findings.

## Tutor guidance

- Tutors should agree research objectives with learner.
- Tutors should check that different types of resource have been used.

## 20.5 Transferable skills – teamwork standards

Evidence must demonstrate the learner can:

<b>TW1</b>	Plan the work with others.	1.1 Agree realistic objectives for working together and what needs to be done in order to achieve them. 1.2 Share relevant information to help agree team roles and responsibilities. 1.3 Agree suitable working arrangements with other team members.
<b>TW2</b>	Develop and maintain cooperative ways of working towards agreed objectives checking progress on the way.	2.1 Organise and complete own tasks efficiently to meet responsibilities. 2.2 Seek effective ways to develop cooperation such as ways to resolve conflict and maintain open communication. 2.3 Share accurate information on progress and agree changes where necessary to achieve objectives.
<b>TW3</b>	Review working with others and agree ways of improving collaborative work in the future.	3.1 Agree the extent to which working with others has been successful and objectives have been met. 3.2 Identify factors, including their own role, in influencing the outcome. 3.3 Provide details of how they could improve working with others in the future, including interpersonal skills.

A group/team is defined as **three or more** people (eg peer, co-worker) who are working towards shared objectives. It is not acceptable for tutors/assessors to be part of the team. The nature of the teamworking should reflect the sector in which the qualification sits, eg engineering, business or IT.

### Required evidence<sup>10</sup>

- Plan\*.
- Do\*.
- Review\*.
- Minutes of meetings.
- Witness statement.
- Peer statements.

### Learner guidance

Meeting the standard will confirm that the learner has:

- demonstrated the ability to work cooperatively with others
- be clear about the objectives the team or group is working towards and their own responsibilities
- planned and carried out the work supporting others, reviewing outcomes and suggesting ways of improving work with others.

Activities must always be contextualised within the core subject content, and should not be simulated.

<sup>10</sup> For evidence marked with an asterisk (\*) recording documents are available for centres to use – please see [aqa.org.uk/tech-levels/transferable-skills](http://aqa.org.uk/tech-levels/transferable-skills)



## TW1

As part of the initial team planning meeting the learner should:

- offer suggestions and listen to others to agree realistic objectives, prioritise tasks and identify resources and timescales
- be clear about their own responsibilities and the areas of work for which they are answerable to others
- produce a plan showing what needs to be done by the team clarifying own responsibilities and arrangements for working with others in the team.

## TW2

Learners should take responsibility for:

- organising their own work to meet the agreed deadlines
- the use of correct and appropriate techniques and approaches when carrying out tasks
- actively looking for ways to develop and support cooperative working, including helping to deal with conflict and taking a lead role in anticipating the needs of others
- considering the rights and feeling of others
- ensuring at least one team progress meeting should be held before the final review meeting.

## TW3

During the team review meeting learners should:

- provide information about their own contribution to the work of the team ie what did they do and how did they interact with other members of the group
- explain how improved inter-personal skills could contribute to more effective collaboration in the future (for example 'I should listen more carefully when negotiating activities/tasks')
- identify improvements they could make in managing tasks (for example 'I could have been better organised with notes at team meetings').

## Tutor guidance

Tutors are encouraged to support the evidence process by completing a witness statement.

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## Get help and support

Visit our website for information, guidance, support and resources at [aqa.org.uk/tech-levels](https://aqa.org.uk/tech-levels)

E: [techlevels@aca.org.uk](mailto:techlevels@aca.org.uk)

T: 0800 085 0391