

# Specification

Edexcel Diplomas

Edexcel Level 3 Principal Learning in Engineering

Issue 4

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This specification is Issue 4. We will inform centres of any changes to this issue. The latest issue can be found on the Edexcel website: [www.edexcel.com](http://www.edexcel.com)

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# Structure and aims of Principal Learning in Engineering

## The Edexcel Diplomas in Engineering: Principal Learning

The Edexcel Diplomas in Engineering aim to:

- Develop a broad understanding and knowledge about engineering and related sectors.
- Develop the knowledge, skills and attributes required to work in the engineering sector.
- Encourage learners to learn through experience of applying knowledge and skills to tasks or contexts including those that have many of the characteristics of real work.
- Support equality and diversity by considering the needs of all potential learners, to minimise any later need to make reasonable adjustments for learners who have particular requirements.
- Encourage learners to develop and apply functional skills in mathematics, English and ICT at the appropriate level (Level 1 in Level 1 Diplomas, Level 2 in Level 2 Diplomas and Level 2 in Level 3 Diplomas).
- Encourage learners to develop and apply transferable personal, learning and thinking skills (in independent enquiry, creative thinking, reflective learning, team working, self-managing and effective participation).
- Encourage learners to draw out and articulate lessons learnt (both generalised and specific).
- Encourage learners to plan, review and reflect on their experience.
- Develop learners' understanding of spiritual, moral, ethical, social, legislative, economic and cultural issues, where appropriate to the engineering sector.
- Develop understanding of sustainable development, health and safety considerations and European developments, consistent with international agreements.

## Edexcel Level 3 Principal Learning in Engineering

All units are compulsory.

Unit number	Title	GLH	Assessment
1	Investigating Engineering Business and the Environment	60	External
2	Applications of Computer Aided Designing	60	Internal
3	Selection and Application of Engineering Materials	60	Internal
4	Instrumentation and Control Engineering	60	Internal
5	Maintaining Engineering Plant, Equipment and Systems	30	Internal
6	Investigating Modern Manufacturing Techniques Used in Engineering	60	Internal
7	Innovative Design and Enterprise	60	Internal
8	Mathematical Techniques and Applications for Engineers	60	External
9	Principles and Application of Engineering Science	90	Internal

# Unit format

All units in Edexcel Principal Learning qualifications have a standard format which is designed to provide clear guidance on the requirements of the qualification for learners, tutors, assessors and those responsible for monitoring national standards.

Each unit is set out in the following way:

<b>Unit title</b>	The unit title is accredited by QCDA and this form of words will appear on the learner's Notification of Performance (NOP).
<b>Level</b>	This is the level of study of the qualification.
<b>Internal/external assessment</b>	Further details of the mode of assessment are given later in the unit.
<b>Guided learning hours (GLH)</b>	<p>In the Principal Learning qualifications each unit consists of 30, 60 or 90 guided learning hours depending on the level.</p> <p>Guided learning hours is 'a notional measure of the substance of a unit'. It includes an estimate of time that might be allocated to direct teaching, instruction and assessment, together with other structured learning time such as directed assignments or supported individual study. It excludes learner-initiated private study.</p> <p>Centres are advised to consider this definition when planning the programme of study associated with this specification.</p>
<b>About this unit</b>	<p>This section is designed to give the reader an appreciation of the value of the unit in the vocational setting of the qualification as well as highlighting the focus of the unit.</p> <p>It provides the reader with a snapshot of the aims of the unit and the key knowledge, skills and understanding developed while studying the unit. The unit abstract also emphasises links to the sector by describing what the unit offers the sector.</p>
<b>Learning outcomes</b>	Learning outcomes state exactly what a learner should 'know', 'understand' or 'be able to' do as a result of completing the unit.
<b>What you need to cover</b>	<p>This section identifies the depth and breadth of knowledge, skills and understanding needed to achieve each of the learning outcomes. This is illustrated by the range of subject material for the programme of learning and specifies the skills, knowledge and understanding required for achievement to the level required to comply with all mark bands.</p> <p>Each learning outcome is stated in full and then expanded with further detail on the right-hand side. Internally assessed units may contain 'egs' within this section. These are used to show indicative lists of content only.</p>

<b>Learning outcomes and assessment criteria</b>	This section contains learning outcomes and assessment criteria for the externally assessed units. Learning outcomes and assessment criteria for internally assessed units can be found in <i>Annexe F</i> .
<b>How you will be assessed</b>	This section gives information about the assessment activities required for this unit.
<b>Marking grid</b>	Internally assessed units have a marking grid which contains a list of assessment foci, with statements ordered into three mark bands. When work is marked it is judged against these statements and an appropriate mark awarded.
<b>Guidance for teaching this unit</b>	<p>This section is designed to give tutors additional guidance and amplification on the unit in order to provide a coherence of understanding and a consistency of delivery and assessment. This section includes guidance on:</p> <ul style="list-style-type: none"> <li>• <i>Delivery</i> – this could, for example, explain the relationship between the content and the learning outcomes or guidance about possible approaches to delivery.</li> <li>• <i>Assessment</i> – this could provide amplification about the nature and type of evidence that learners need to produce in order to pass the unit or achieve the higher marks. This section should be read in conjunction with the marking grid.</li> </ul> <p><i>Personal, learning and thinking skills (PLTS)</i> – this section identifies where there may be opportunities within the unit for the generation of evidence to meet the requirements of PLTS.</p> <p>Assessors should take care to become familiar with PLTS and not to rely on the contents of this section when presenting evidence for moderation. The full PLTS framework is included in this document as <i>Annexe B</i>, but centres should refer to the QCDA website (<a href="http://www.qcda.gov.uk">www.qcda.gov.uk</a>) for the latest version of the PLTS framework.</p> <p><i>Functional skills</i> – this section identifies where there may be opportunities within the unit for the generation of evidence to meet the functional skill requirements.</p> <p>This section will also provide guidance relating to <i>Work experience, Specialist resources</i> and <i>Reference materials</i>.</p>

# Assessment and grading of the Principal Learning

The purpose of assessment is to ensure that effective learning of each unit has taken place. Principal Learning units are assessed either internally by tutors or externally by Edexcel. Each unit is labelled clearly as internally or externally assessed.

It is essential that tutors familiarise themselves with and follow the guidelines set out in the document *Internal Assessment of Principal Learning Units: Controls for Task Setting, Task Taking and Task Marking – for Principal Learning in Construction and the Built Environment, Creative and Media, Engineering, Information Technology and Society, Health and Development* (see *Annexe E*) when developing assignments for internally assessed units.

## Internal assessment

Internal assessment will be used to facilitate assessment of generic and practical skills. It will be quality assured through internal and external moderation. It will be supervised and completed under controlled conditions.

Each unit is assessed through a single **assignment** which has an overall purpose that reflects the aim of the unit, and is described in the *How you will be assessed* section. An **assignment** may be broken down into a few separate **tasks**. Tasks may be further broken down into smaller activities. The *Internal Assessment of Principal Learning Units: Controls for Task Setting, Task Taking and Task Marking – for Principal Learning in Construction and the Built Environment, Creative and Media, Engineering, Information Technology and Society, Health and Development* document details the nature of the controls that need to be applied to each type of task/activity and its outcome.

Where a unit is internally assessed, centres can use the sample assignments provided by Edexcel, or can design and quality assure suitable assignments. When designing assignments, centres are required to be aware of the following design principles (see relevant Tutor Support Materials for further guidance).

Assignments should be:

Fit for purpose	<i>They should consist of tasks which are related to the subject matter and content of the unit. For example, where a unit is centred on IT, the assessment will use IT at the core of the task.</i>
Manageable	<i>They should be designed to be manageable for both the learner and for the centre.</i>
Secure	<i>They should be delivered under controlled conditions, where centres can guarantee the work produced is truly that of the individual learner.</i>
Reliable	<i>They should produce judgements of a similar standard from occasion to occasion and between different assessors.</i>
Valid	<i>They should assess what they are intended to assess in terms of the learning outcomes.</i>
Transparent	<i>They should be expressed in ways that can be readily understood by learners, tutors and assessors.</i>
Balanced	<i>They should fairly reflect the content and associated learning outcomes, avoiding confusing learning with assessment and not adversely affecting teaching and learning.</i>
Flexible	<i>They should provide opportunities for learners to produce a variety of different forms of evidence.</i>

Centres are encouraged to use a variety of assessment methods, which might include, for example, the use of case studies, work-based assessments, projects, performance observation and time-constrained assessments. Centres are encouraged to place emphasis on practical application, providing a realistic scenario for learners to adopt, and making maximum use of practical activities and work experience.

The creation of assignments that are **fit for purpose** is vital to learners' achievement and its importance cannot be over emphasised.

When reading the marking grids and designing assignments, centres should note the following.

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## External assessment

There is a requirement that some units in the Principal Learning will be externally assessed. These external assessments will be made available by Edexcel on agreed, published dates during the year.

For the Principal Learning in Engineering the following units will be externally assessed:

Level	Unit number(s)	Unit title(s)
Advanced	Unit 1	Investigating Engineering Business and the Environment
	Unit 8	Mathematical Techniques and Applications for Engineers

## Calculation of the Principal Learning grade

Performance in each unit of Principal Learning will be assessed against criteria given in the marking grid, giving rise to unit **marks**.

Unit marks will be allocated according to marking criteria that do not bear a direct relationship to grading mark bands; that is, assessors will be clear that they are allocating **marks** and are not grading learners directly.

There will be no pre-published unit grade boundaries.

Once units have been completed by learners and marked, they will be graded by Edexcel through a separate process involving professional judgement of performance and of technical and statistical data. This will produce unit grade boundaries and hence unit grades which will be reported.

To permit the calculation of a Principal Learning qualification grade, Principal Learning unit marks will be converted to **points**. Points for all Principal Learning units will be added together to devise a Principal Learning score. Using published thresholds the Principal Learning score will be converted to a Principal Learning grade.

## Calculation of the Diploma grade

The overall grade for the Diploma will be based only on grades obtained from Principal Learning and the project. However, achievement of **all** components within the Diploma will be required in order to gain the Diploma qualification.

Points for Principal Learning units (weighted as appropriate) will be added to points for the project to derive a Diploma **score**. Using published thresholds the Diploma score will be converted into a Diploma grade.

# Programme design and delivery

These Principal Learning qualifications consist of units of assessment. Each unit is 30, 60, or 90 guided learning hours in length depending on the level. The definition of guided learning hours is 'a notional measure of the substance of a qualification'. It includes an estimate of time that might be allocated to direct teaching, instruction and assessment, together with other structured learning time such as directed assignments or supported individual study. It excludes learner-initiated private study. Centres are advised to consider this definition when planning the programme of study associated with this specification.

## Mode of study

Edexcel does not define the mode of study for the Principal Learning of Diplomas but there is an explicit requirement that for at least 50 per cent of the time learners will be engaged in applied learning.

### Applied learning

Acquiring and applying knowledge, skills and understanding through tasks set in sector contexts that have many of the characteristics of real work, or are set within the workplace. Most importantly, the purpose of the task in which learners apply their knowledge, skills and understanding must be relevant to real work in the sector.

Reference: *The Diploma* (Qualifications and Curriculum Authority, 2007)

Centres are free to offer the qualifications using any mode of delivery that meets the needs of their learners and the requirements of applied learning. For example this may be through a combination of traditional classroom teaching, open learning and distance learning. Whatever mode of delivery is used, centres must ensure that learners have appropriate access to the required resources (see individual units) and to the subject specialists delivering the units.

Assignments based on the work environment should be encouraged. Those planning the programme should aim to enhance the vocational nature of the Diploma by:

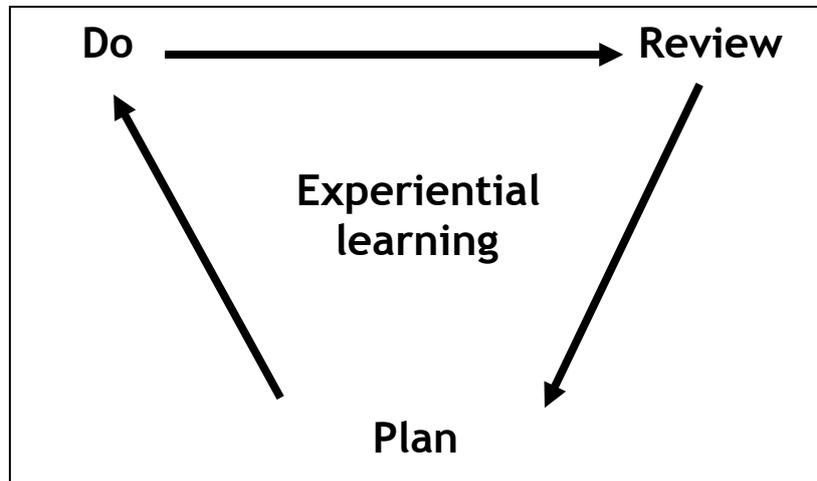
- liaising with employers to ensure a course relevant to the specific needs of the learners
- accessing and using non-confidential data and documents from workplaces
- including sponsoring employers in the delivery of the programme and, where appropriate, in the assessment
- linking with company-based/workplace training programmes
- making full use of the variety of experience of work and life that learners bring to the programme.

## Delivery of applied learning

It is important that centres develop an approach to teaching and learning that supports the applied learning requirement of the Diploma. The Principal Learning specifications contain a balance of practical skill development and knowledge requirements, some of which can be theoretical in nature. Tutors and assessors need to ensure that appropriate links are made between theory and practice and that the knowledge base is applied to the sector. This will require the development of relevant and up-to-date teaching materials that allow learners to apply their learning to actual events and activity within the sector.

Tutors are reminded that **experiential learning** techniques are required and that the opportunities for formative assessment where learners benefit from regular and structured feedback are a necessary requirement of a Diploma programme.

Where learners are performing an activity by practically applying their knowledge and skills, they are essentially behaving in the required applied nature of the Diploma. By then reviewing that learning and considering how improvements can be made and implemented, experiential learning will take place (see *Figure 1*).



*Figure 1: Experiential learning cycle*

## Resources

One aim of Diplomas is to prepare learners to progress to employment in specific sectors. Physical resources need to support the delivery of the programme and the proper assessment of the learning outcomes and therefore should normally be of industry standard.

Staff delivering programmes and conducting the assessments should be fully familiar with current practice and standards in the sector concerned.

Centres will need to meet any specialist resource requirements when they seek approval from Edexcel.

## Assessment and learning

### Summative assessment

Summative assessment serves to inform an overall judgement of achievement, which may be needed for reporting and review, perhaps on transfer between years in a school or on transfer between schools, perhaps for providing certificates at the end of schooling.

Although learners are working to satisfy a summative assessment (the marking grids reflect a final overall judgement) the benefit of formative assessment should be strongly emphasised throughout the learning.

### Formative assessment

Formative assessment is concerned with the short-term collection and use of evidence as guidance of learning, mainly in day-to-day classroom practice.

In order for formative assessment to occur, the learner must understand what they have learned, what they have yet to learn and what they need to do to learn it. The responsibility of helping learners through a process of planning and reviewing their learning lies with the tutor.

## Personal, learning and thinking skills (PLTS)

Personal, learning and thinking skills are necessary for work and for general learning. Learners will have opportunities to develop, apply and assess all the personal, learning and thinking skills within Principal Learning. Personal, learning and thinking skills consist of the following six skills:

- independent enquiry
- creative thinking
- reflective learning
- team working
- self-management
- effective participation.

*Annexe B* contains detailed information relating to each of the six personal, learning and thinking skills.

Each unit requires learners to demonstrate personal, learning and thinking skills, which are a mandatory requirement and a key feature of the Diplomas. Personal, learning and thinking skills are to be used as both a guide on the delivery of each unit and also as a motivating formative indicator for the learner.

### Coverage

All personal, learning and thinking skills are required to be covered and assessed during the delivery and assessment of the whole Diploma and provide the context for the delivery and assessment of the programme of learning. A final summary of the coverage is also provided in *Annexe B* which collates the coverage of personal, learning and thinking skills throughout the programme.

Personal, learning and thinking skills are an essential, embedded feature of the delivery and assessment of the Principal Learning. Learners may also develop and apply personal, learning and thinking skills within the other components of the Diploma.

Centres should design the programme of study so that approximately 60 GLH will be allowed to enable learners to develop, plan and review the application of their personal, learning and thinking skills across their learning programme. Personal, learning and thinking skills will not be separately assessed as part of the Diploma but all six personal, learning and thinking skills will be integrated into the assessment criteria for Principal Learning. Each learner's achievement of personal, learning and thinking skills will be recorded in the Diploma transcript.

## How personal, learning and thinking skills are used to support formative feedback

Personal, learning and thinking skills provide an excellent structural guide for the tutor when providing formative feedback to the learner. Tutors will be able to structure assessment and learning opportunities around personal, learning and thinking skills and should use a pro forma sheet to indicate to the learner where progress has been made and where the learner needs to focus further development. A suggested sheet ('PLTS Performance Indicator') for this activity is provided in *Annexe B*.

The 'PLTS Performance Indicator' can be used by the assessor to feed back on work to the learner showing the level of success that has been demonstrated during each assignment. The indicator is filled in by the assessor or supervisor to record the learner's performance at regular intervals during the course and ideally after every assignment. This informs the learner of their strengths and weaknesses and illustrates graphically where the learner should concentrate their efforts in the future.

## Access and recruitment

Edexcel's policy regarding access to its qualifications is that:

- the qualifications should be available to everyone who is capable of reaching the required standards
- the qualifications should be free from any barriers that restrict access and progression
- there should be equal opportunities for all wishing to access the qualifications.

Centres are required to recruit learners to Edexcel qualifications with integrity. This will include ensuring that applicants have appropriate information and advice about the qualifications and that the qualification will meet their needs.

Centres should take appropriate steps to assess each applicant's potential and make a professional judgement about their ability to successfully complete the programme of study and achieve the qualification. This assessment will need to take account of the support available to the learner within the centre during their programme of study and any specific support that might be necessary to allow the learner to access the assessment for the qualification. Centres should also show regard for Edexcel's policy on learners with particular requirements.

### Access arrangements and special considerations

Edexcel's policy on access arrangements and special considerations aims to enhance access to the qualifications for learners with disabilities and other difficulties (as defined by the Disability Discrimination Act 1995 and the amendments to the Act) without compromising the assessment of skills, knowledge, understanding or competence.

## Further information

For further information please call Customer Services on 0844 576 0028 (calls may be recorded for training purposes) or visit our website at [www.edexcel.com](http://www.edexcel.com).

### Useful publications

Further copies of this document and related publications can be obtained from:

Edexcel Publications  
Adamsway  
Mansfield  
Nottinghamshire NG18 4FN

Telephone: 01623 467 467  
Fax: 01623 450 481  
Email: [publication.orders@edexcel.com](mailto:publication.orders@edexcel.com)

Related information and publications include:

- *Accreditation of Prior Learning* available on our website: [www.edexcel.com](http://www.edexcel.com)
- *Guidance for Centres Offering Edexcel/BTEC NQF Accredited Programmes* (Edexcel, distributed to centres annually)
- *Operating Rules for Component and Diploma Awarding Bodies* (QCA, 2007)
- *The Diploma Structure and Standards, Version 2* (QCA, 2007)
- *Regulatory Arrangements for the Qualification and Credit Framework* (Ofqual, August 2008)
- *What is a Diploma?* (DfES and QCA, 2007)
- the ASL catalogue on the National Database of Accredited Qualifications (NDAQ) website: [www.ndaq.org.uk](http://www.ndaq.org.uk)
- the current Edexcel publications catalogue and update catalogue
- the latest news on the Diploma from QCDA available on their website: [www.qcda.gov.uk/diploma](http://www.qcda.gov.uk/diploma)
- the latest news on Edexcel Diplomas available on our website: [www.edexcel.com/quals/diploma](http://www.edexcel.com/quals/diploma)

NB: Most of our publications are priced. There is also a charge for postage and packing. Please check the cost when you order.

# Professional development and training

Edexcel supports UK and international customers with training related to our qualifications. This support is available through a choice of training options offered in our published training directory or through customised training at your centre.

The support we offer focuses on a range of issues including:

- planning for the delivery of a new programme
- planning for assessment and grading
- developing effective assignments
- building your team and teamwork skills
- developing student-centred learning and teaching approaches
- building key skills into your programme
- building in effective and efficient quality assurance systems.

The national programme of training we offer can be viewed on our website ([www.edexcel.com/training](http://www.edexcel.com/training)). You can request customised training through the website or by contacting one of our advisers in the Professional Development and Training team via Customer Services to discuss your training needs.

Our customer service numbers are:

The Diploma	0844 576 0028
BTEC and NVQ	0844 576 0026
GCSE	0844 576 0027
GCE	0844 576 0025
DIDA and other qualifications	0844 576 0031

Calls may be recorded for training purposes.

The training we provide:

- is active – ideas are developed and applied
- is designed to be supportive and thought provoking
- builds on best practice.

# Level 3 units



# Unit 1: Investigating Engineering Business and the Environment

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**Principal Learning unit**

**Level 3**

**Guided Learning Hours: 60**

**Externally assessed**

**(58.5 hours learning time and 1.5 hours for assessment)**

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## About this unit

Have you ever wondered how leading businessmen like Sir Alan Sugar and Sir Richard Branson developed companies with multi-million turnovers? Or why they were successful when their competitors failed? The success of one business over another can be attributed to many factors.

Like Amstrad and Virgin, all engineering companies operate as businesses and, because of this, engineers and technicians need to have an understanding of how a company is organised and how a business operates. This knowledge is essential for anyone wishing to develop a career in engineering and for those who might eventually want to own and run their own engineering businesses.

This unit will help you develop your understanding of business, the commercial aspects of engineering and its effects on the environment. It will also provide you with a firm foundation for employment in the engineering sector and an understanding of the organisational, financial, legal, social and environmental constraints within which an engineering company operates.

The unit also allows you to consider the use and implication of costing techniques on the sustainability of a particular engineering activity. You will also have the opportunity to investigate how a real engineering company operates, including an understanding of the factors that affect its profitability.

In order to develop an understanding of the impact of health and safety on how an engineering company operates, you will examine relevant legislation and also conduct a risk assessment for an engineering activity.

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## Learning outcomes

On completion of this unit, a learner should:

- LO.1. Know how an engineering business is structured and how it operates
  - LO.2. Know about internal and external factors that affect the way in which an engineering business operates
  - LO.3. Know about and apply financial and planning concepts, and costing and planning techniques
  - LO.4. Know the importance of legislation concerning health and safety including a risk assessment for an engineering activity.
-

## What you need to cover

- LO.1 Know how an engineering business is structured and how it operates**
- Learners will need to examine the main types of organisation and how they are classified in terms of size, eg micro, small, medium, large; status, eg sole trader, partnership, public (plc), private (Ltd), new, established, charitable, not for profit; structure, eg owner-manager, boards, committees, governors, hierarchical, divisional, flat, matrix.
- Learners will also need to find out about the sectors in which an engineering business operates and how they are classified as primary, eg oil, gas, agriculture; secondary, eg, chemical, manufacture, automotive, aerospace, marine; or tertiary, eg energy distribution, nuclear technologies, waste management, water services, building services, civil, construction, structural, health, telecommunications.
- Learners will need to investigate the engineering functions that are performed within an engineering company, eg research and development (R&D), design, manufacture, materials supply and control, production planning and control, installation, commissioning, maintenance, technical support, technical sales, project planning and management, quality assurance.
- Learners will also need to know about the form, content and flow of information in an engineering company, eg work instructions (such as operation sheets, engineering drawings, circuit diagrams), specifications, material and component requisitions, stock levels, records of work in progress, stock/orders/sales, internal and external lines of communication, working procedures, protocols and ethics of communication.
- LO.2 Know about internal and external factors that affect the way in which an engineering business operates**
- Learners will need to investigate the internal factors that affect the way in which an engineering business operates, eg production capacity; production methods (prototype, batch, continuous flow); design capability; tooling; product and technology experience.
- They will also need to find out about the external factors that affect the way in which an engineering business operates, eg markets, consumers, demographic and social trends, competitive products/services/organisations, customer/client relationships, innovation and technological change, availability of sustainable resources.
- Learners will need to investigate the economic environment that affect the way in which an engineering business operates, eg gross national product (GNP); gross domestic product (GDP); balance of payments; local economy; regional and national economy (such as regional development agency, local/regional skills targets); global economy; interest rates; exchange rates.
- Learners will need to know about the environmental and social factors that affect the way an engineering business operates, eg sustainability, environmental impact, use of renewable resources, by products, pollutants and waste products; social constraints, eg employment levels, workforce skill levels and training requirement/opportunities, impact of outsourcing.

<b>LO.3 Know about and apply financial and planning concepts, and costing and planning techniques</b>	<p>Learners will need to find out about basic financial concepts, eg income, expenditure, profit/loss, indirect cost, fixed cost, variable cost, contribution, marginal costing; assets, eg investment, value and depreciation of fixed assets.</p> <p>Learners will need to apply costing techniques to determine the cost effectiveness of an engineering activity, eg job costing, process costing, absorption costing, make or buy decisions, break-even point, investment appraisal.</p> <p>Learners will investigate basic planning concepts, eg short-term and long-term plans, standing plans, business plans, financial plans, budget plans, charts and scheduling techniques (flow charts, Gantt charts, critical path methods, software packages), setting priorities, monitoring and resource control.</p> <p>Learners will also apply planning techniques to determine the feasibility and critical path for a time constrained engineering activity, eg the design, manufacture, installation and commissioning of an engineered product.</p>
<b>LO.4 Know the importance of legislation concerning health and safety including a risk assessment for an engineering activity</b>	<p>Learners will need to find out about the legislation and regulations that relate to an engineering business, eg Health and Safety at Work Act 1974, Employment Act 2002, Factories Act 1961, Fire Precautions Act 1971; regulations, eg The Employment Equality (Age) Regulations 2006, Management of Health and Safety at Work Regulations 1999, Provision and use of Work Equipment Regulations 1998, Control of Substances Hazardous to Health Regulations (COSHH) 2002, Lifting Operations and Lifting Equipment Regulations 1998, Manual Handling Operations Regulations 1992, Personal Protective Equipment at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Noise at Work Regulations 1989, reportable Injuries Diseases and Dangerous Occurrences Regulations 1998, Working Time Regulations 1998, The Workplace (Health, Safety and Welfare) Regulations 1992, Health and Safety (First Aid) Regulations 1981, Control of Noise at Work Regulations 2005, reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Working Time Regulations 1998, Workplace (Health, Safety and Welfare) Regulations 1992, Health and Safety (First Aid) Regulations 1981, Supply of Machinery (Safety) (Amendment) Regulations 2005 (SI 2005/831).</p> <p>Learners will need to know about the roles and responsibilities of individuals and bodies involved with health and safety, eg employers; employees; Health and Safety Executive (HSE), eg span of authority, right of inspection, guidance notes and booklets; others, eg management, sub-contractors, public, suppliers, customers, visitors.</p>

Learners will also research the use of control measures in relation to health and safety, eg removal of need (design out), use of recognised procedures, substances control, guarding, lifting assessments and manual handling assessments, regular inspection, use of Personal Protective Equipment (PPE), training of personnel, other personal procedures for health, safety and welfare.

Learners will carry out a risk assessment for an engineering activity, eg use of a lathe to remove metal, use of soldering equipment to make soldered joints on an electronic circuit board.

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## Learning outcomes and assessment criteria for each unit

Learning outcome number	Learning outcome	Assessment criteria
	The learner should:	The learner can:
LO.1	Know how an engineering business is structured and how it operates	<p>Identify types of engineering companies, the sectors in which an engineering company operates, explain the functions within an engineering company and review its structure and organisation.</p> <p>Identify, describe and explain the types, form, content and flow of information that are essential for the operation of an engineering company.</p>
LO.2	Know about internal and external factors that affect the way in which an engineering business operates	<p>Identify and describe the internal and external factors that affect the way in which an engineering company operates.</p> <p>Explain strategic decisions made by an engineering business that arise from economic, environmental or social factors.</p>
LO.3	Know about and apply financial and planning concepts, and costing and planning techniques	<p>Identify, explain and apply appropriate financial concepts and costing techniques to determine cost-effectiveness of an engineering activity.</p> <p>Identify, explain and apply planning concepts and techniques and determine the critical path and time required to perform an engineering activity.</p>
LO.4	Know the importance of legislation concerning health and safety including a risk assessment for an engineering activity	<p>Explain health and safety legislation and other regulations and the related control measures that apply to engineering activities, including the use of risk assessments and how they are carried out.</p>

## How you will be assessed

This unit is externally assessed by means of a written paper containing multiple-choice questions, short-answer questions and long-answer questions. You will sit the assessment under formal examination conditions.

## Guidance for teaching this unit

### Delivery and assessment guidance

The delivery strategy used should emphasise the strong links between the learning outcomes. Learners need to gain a coherent view of business systems within an engineering context. This includes how engineering companies operate, the factors that impact upon them (including economic and legislative factors), set within an understanding of the financial needs of being in business. Learners need to not only appreciate the importance and value of their role in the business but also have a wider appreciation of the business of engineering.

The focus of delivery will depend on the centre's ability to access engineering business organisations. Ideally, centres will have industry links for learners who are able to go on work placements. Alternatively, delivery could be achieved through case studies of local engineering companies that may provide employment opportunities for learners. It is likely that a case study approach would need to be supported by a range of industry visits to enable learners to put the size and scope of engineering as an industry into perspective.

Industry visits should form an important part of the delivery strategy. Seeing a variety of engineering companies will provide learners with a much greater appreciation of the diverse nature of the different engineering sectors. This appreciation should include an understanding that engineering is virtually everywhere and not just limited to the more conventional forms of manufacture often depicted in the media. It could be reinforced by making it clear how learners' own music systems are 'engineered' or how the building in which they are studying relies on engineering – the overall structure of the building, its structural materials, the equipment it contains, its maintenance.

The methods of delivery should, as far as possible, be activity based. The learning activities could make use of case studies, researching actual engineering businesses and industry visits. Examples of case studies could include examining structures of engineering organisations, information systems, historical views of changing economic and social environments, the impact of legislation and regulations on a specific engineering company. If learners are employed then it could be useful for them to research aspects of their own company and make comparisons with other industries. For example, a learner working in a small limited company, with only five or six staff, could examine how the business functions of larger organisations (research and design, maintenance, technical sales etc) are carried out or vice versa.

Activities could also be set around video footage with learners reviewing a programme (eg on current affairs such as the impact of outsourcing and the global economy or business improvement). Groups of learners could then prepare a presentation (eg poster, formal presentation) of their findings in terms of the engineering functions, information flow, interdependent approaches and so on.

Tutors could use role play, gaming or modelling to good effect. For example, a modelling exercise to manufacture a particular item (real or imaginary) could lead to an examination of everything from the company required to manufacture it, the legislation and regulations that will impact upon any manufacturing or business tasks carried out, to a determination of cost and likely profit or loss.

The ultimate purpose of the delivery strategy must be to provide learners with as wide an experience as possible of engineering business functions, in all their forms. If learners are to be able to work in a truly independent way but also interdependently within an organisation, they will need a sound understanding of the principles of how engineering companies operate.

Centres will need to carefully consider when this unit is to be delivered within the programme of learning. To be truly effective, the unit requires learners to have an appreciation of the core aspects of the engineering processes being studied (eg manufacturing/production processes) and the language of engineering. This is because they will be exposed to these concepts very quickly as they begin to examine the functions of engineering companies.

The external assessment is in the form of an examination which has three sections. The examination paper is made up of 20 multiple-choice questions, about four short-answer questions and about two long-answer questions. All questions are marked against a marking scheme.

**Guidance for the delivery of personal, learning and thinking skills (PLTS)**

Although PLTS are not identified within this unit as an inherent part of the assessment criteria, there are opportunities to develop a range of PLTS through various approaches to teaching and learning. (*Annexe B* of this document lists the personal, learning and thinking skills and their elements.)

Skill	When learners are ...
<b>Independent enquirers</b>	Identifying coursework questions and problems to resolve. Seeking information and carrying out case studies; investigating costing and planning techniques; obtaining economic, social and environmental data. Identifying and apply basic costing techniques, and identifying and apply basic planning techniques. Assessment focus 3.
<b>Creative thinkers</b>	Identifying the implications of risk assessment, health and safety legislation and other regulations that apply to engineering activities. Assessment focus 4.
<b>Reflective learners</b>	Setting goals for the development of each of their assignments. Reviewing their progress against the completion of their assignments. Evaluating results of case studies and activities; checking that answers to problems involving costing, cost-effectiveness, and planning are realistic and within an appropriate range. Identifying and apply basic costing techniques, and identifying and applying basic planning techniques. Assessment focus 3.
<b>Team workers</b>	Not present in this unit.
<b>Self-managers</b>	Planning and organising the creation of their assignments for this unit. Dealing with time pressures and deadlines for the production of their assignments. Seeking advice and support from their peers and tutors when needed.
<b>Effective participators</b>	Not present in this unit.

## Functional skills – Level 2

This unit provides opportunities for the development of some of the functional skills in mathematics. In particular when learners are entering and manipulating data and when using appropriate mathematical procedures with numerical solutions (such as those involved with costing and planning). They will develop skills in presenting data in different forms when analysing data and will develop proficiency in sketching diagrams and plotting graphs (such as break-even charts, organisational structures, etc).

### Work experience

This unit could make good use of work placements. Learning about a real engineering company's organisation, functions and how information flows through the company will enhance learner understanding. Engineering companies are likely to have internal and external factors that learners could investigate and make recommendations to reduce any negative effects.

### Specialist resources

Learners require access to sufficient data on engineering companies. This can be in the form of case studies, industry visits or data available through learners' work placements. Videos and topical news items relating to the economy, changes in legislation and social factors can be used as a stimulus for class discussion and as a background to activities and case studies.



## Unit 2: Applications of Computer Aided Designing

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Principal Learning unit

Level 3

Guided Learning Hours: 60

Internally assessed

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### About this unit

Engineering design used to involve many hours laboriously spent at a drawing board, but these days the use of computer software packages for design and presentation purposes has become standard practice. Packages range from relatively simple 2D CAD (two-dimensional Computer Aided Design) to much more complex 3-dimensional solid models and real-image representations. Another exciting development is the linking of the design and pre-production functions by virtual analysis and testing software, which is used to check the suitability and performance of materials and components under operating conditions.

This unit will give you access to all of these types of software and will give you the skills and knowledge needed to use them for producing drawings and testing purposes.

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### Learning outcomes

On completion of this unit, a learner should:

- LO.1. Know about computer systems and methods of data storage
  - LO.2. Know about the capabilities of design, presentation, testing and analysis software packages and how they are used as tools within engineering
  - LO.3. Be able to use a CAD package to produce 2D drawings
  - LO.4. Be able to use design software to produce 3D models for use as presentation drawings or as data for other software uses
  - LO.5. Be able to use testing and analysis simulation software as a design support tool.
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## What you need to cover

- |   |  |
|---|--|
| <b>LO.1 Know about computer systems and methods of data storage</b>   | Learners will need to know about the component parts of a computer system including data input and output devices, processors, operating systems and data storage devices.   |
| <b>LO.2 Know about the capabilities of design, presentation, testing and analysis software packages and how they are used as tools within engineering</b> | <p>Learners will need to investigate the application of computers and computer software for design purposes within the engineering industry. They will need to know how they can be used to design components and assemblies for manufacture, produce three-dimensional models for presentation purposes and test for material/component operation and performance.</p> <p>Learners will also find out how the differing types of individual software package can be combined to form integral parts of the design and pre-production process.</p> |
| <b>LO.3 Be able to use a CAD package to produce 2D drawings</b>   | <p>Learners will need to demonstrate how to use the 2D CAD features of a CAD software package to enable production of working drawings and specifications for engineered components and assemblies in orthographic and isometric projections, system diagrams (pneumatic, hydraulic) and circuit diagrams (electrical and electronic).</p> <p>Learners' drawings should be produced to an appropriate and recognised standard, for example BS8888.2000.</p>  |
| <b>LO.4. Be able to use design software to produce 3D models for use as presentation drawings or as data for other software uses</b>                      | <p>Learners will research the use and features of a 3D CAD and modelling software package to enable the production of wire-frame drawings, wire frame with hidden line removal and rendered solid models.</p> <p>Learners will also save the models in formats that enable their use for designs or presentation purposes.</p>   |
| <b>LO.5 Be able to use testing and analysis simulation software as a design support tool</b>  | <p>Learners will need to use simulation software to model the performance of a product/system or to analyse the effects of loading on the materials used in the building of an object such as a framework.</p> <p>They will also find out how the results of simulation can be used to assess whether a proposed design will meet the requirements of its technical specification and the steps to be taken if modifications to the design are needed in order to make it conform to specification.</p>  |
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## How you will be assessed

This unit will focus on your use of CAD hardware and software to produce 2D drawings, 3D models and simulations to carry out testing and analysis. You will also need to demonstrate that you know about computer systems, data storage and other capabilities of software packages. As such you will be assessed through the theme of the work of a design engineer carrying out functions associated with design work.

The unit will be assessed by your tutor who will set an assignment for you to complete. You are likely to be given a number of tasks that will cover the material you have studied and provide you with opportunities to develop assessment evidence.

The assessment evidence for this unit could typically consist of four tasks, although these do not have to be taken separately. For example, task 1 could cover assessment foci 1 and 2 and may be an investigative task requiring you to look at both computer systems and specific software packages. The evidence for this first task is likely to be in the form of a 'report'.

Task 2 could be about using CAD software to produce 2D drawings in accordance with recognised standards (eg BS:8888.2000) to meet the requirements of assessment focus 3. The evidence for 3 will be a 'process portfolio' that contains all the 2D CAD drawings that have been produced plus other supporting evidence.

Task 3 could be about using design software to produce 3D models to meet the requirements of assessment focus 4 and the evidence could also be in the form of a 'process portfolio'.

Task 4 could be a practical activity based on the use of simulation software to investigate the performance of a product/system/structure, which meets the requirements of assessment focus 5. Gathered data will be presented in the form of a 'process portfolio' which will contain copies of design drawings and a technical specification for the artefact whose performance is being simulated. To achieve marks in the higher bands you will also need to include a 'report'.

## Marking grid

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.1</b> <b>Know about computer systems and methods of data storage</b>	Identifies the component parts of a typical computer system, gives a description of their functions, roles and relationships with data storage.  (0–4)	Identifies the component parts of a typical computer system, gives a description of their functions, roles and relationships with data storage and describes two typical applications of a method of data storage.  (5–8)	Identifies the component parts of a typical computer system, gives a description of their functions, roles and relationships with data storage, describes two typical applications of a method of data storage and compares them in terms of retrieval speed and storage size.  (9–10)	10
<b>LO.2</b> <b>Know about the capabilities of design, presentation, testing and analysis software packages and how they are used as tools within engineering</b>	Explores and states the capabilities of commercially available software selected for the purpose of design, presentation, testing and analysis and gives examples of their use in engineering.  (0–6)	Explores and states the capabilities of commercially available software selected for the purpose of design, presentation, testing and analysis, gives examples of their use in engineering and prepares a case study to illustrate how software can be used in the pre-production of a simple engineered product that requires only one engineering process.  (7–8)	Explores and states the capabilities of commercially available software selected for the purpose of design, presentation, testing and analysis, gives examples of their use in engineering, prepares a case study to illustrate how software can be used in the pre-production of a simple engineered product and identifies how software can be used for more complex products, which involve more than one engineering process.  (9–10)	10

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.3</b> <b>Be able to use a CAD package to produce 2D drawings to British Standards</b>	Produces a 2D CAD working detail drawing and an assembly drawing using orthographic projection.  (0–6)	Produces a 2D CAD working detail drawing and an assembly projection and produces an isometric projection of both drawings.  (7–8)	Produces a 2D CAD working detail drawing and an assembly projection, an isometric projection of both drawings and produces a circuit and a system diagram using representations and symbols.  (9–12)	12
<b>LO.4</b> <b>Be able to use design software to produce 3D models for use as presentation drawings or as data for other software uses</b>	Produces a 3D representation of a simple component as a wire frame drawing and a wire frame with hidden line removal drawing for use as data or as a 3D model.  (0–6)	Produces a 3D representation of a simple component that requires the drawing, surfaces and model to be defined by methods other than simple extrusion of 2D shapes and manipulates the model to display different orientations of the component.  (7–10)	Produces a 3D representation of an industrial component for use as data for other software use or as presentation drawing and image realisation and manipulates the model to display different orientations of the component.  (11–14)	14
<b>LO.5</b> <b>Be able to use testing and analysis simulation software as a design support tool</b>	Conducts a virtual operational performance test or material analysis of a product or material for a given purpose and presents the results for analysis.  (0–6)	Conducts a virtual operational performance test or material analysis of a product or material, and evaluates them against the design specification for the product or material.  (7–10)	Conducts a virtual operational performance test or material analysis of a product or material, presents the results for analysis, evaluates them against the design specification for the product or material and explains the strategy used to resolve issues in the case of non-compliance.  (11–14)	14
<b>Total marks</b>			<b>60</b>	

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to confirm marks within the objective approach. The guidance can then be used to allocate specific marks for that band.

<b>Assessment focus LO.1</b>	
Mark Band 1–3 (0–10 marks)	<p>Up to 2 marks can be awarded for the identification of the system components, and up to 2 marks for describing their function, roles and relationship with the storage of data.</p> <p>The description of the applications should indicate a good understanding of when particular methods of data storage are appropriate for use. Typically, up to 2 marks can be awarded for each of the two types described, although could this go to 3 if one is answered well and above that required for mark band 2, up to a maximum of 4 marks. A statement or list of applications should attract only 1 mark each. The second mark for each is based on the appropriateness of the description.</p> <p>At least two methods of data storage should be compared and up to 2 marks can be awarded for the comparison to include retrieval speed and storage capacities.</p>

<b>Assessment focus LO.2</b>	
Mark Band 1–3 (0–10 marks)	<p>Up to 4 marks can be awarded for exploring an example of software use. Marks should be awarded in relation to the consideration, within the response, of purpose of design, presentation, testing and analysis and up to 2 marks can be awarded for examples given that relate to engineering applications.</p> <p>Up to 2 marks can be awarded for the case study identifying how design and testing software was used within the pre-production process of a relatively straightforward engineered product.</p> <p>One mark could be awarded for the case study relating to a more complex product and 1 mark for the process being described in a more detailed way. This would reward those who carried out research into the product and software to a greater depth.</p>

<b>Assessment focus LO.3</b>	
<p>Mark Band 1 (0–12 marks)</p>	<p>Each of two engineering drawings in orthographic projection should be produced, one being an assembly of a number of parts. For each of the two drawings 1 mark could be awarded for drawing accuracy, 1 mark for appropriate dimensioning and title box, and 1 mark for correct projection and adherence to BS.</p> <p>1 mark could be awarded for each of the two isometric projections.</p> <p>Up to 2 marks can be awarded for each of the two diagrams required, one being of an electrical/electronic circuit and the other a pneumatic/hydraulic system. One mark for each correct diagram and one mark each for the correct use of BS standard symbols. Marks are not to be awarded or lost for the accurate or inaccurate functionality of the circuit or system.</p>

<b>Assessment focus LO.4</b>	
<p>Mark Band 1 (0–14 marks)</p>	<p>Typically up to 3 marks can be awarded for each of the two representations, wire frame and wire frame with hidden line removal. The award of the marks for each will depend on the representation being able to be used as data or as a 3D model. Just a printed drawing would attract minimum marks. Features demonstrating the representations as being fit for the use as data or a 3D model must be visible for all 3 marks to be awarded for each.</p> <p>To gain the marks from mark band 2, learners should display a greater knowledge and aptitude in the use of the software by the production of a more complex nature. Up to 2 marks can be awarded for the increase in complexity over that seen in mark band 1, one that is defined by methods other than simple extrusion of 2D shapes, and up to 2 marks for use of the software to manipulate and orientate the models on screen.</p> <p>Up to 4 marks can be awarded to those producing components of industrial complexity and quality. Marks should be apportioned with regard to the degree of complexity displayed. For all 4 marks to be awarded it is important that the drawing and model can be used by other software or as a presentation drawing and image realisation.</p>

<b>Assessment focus LO.5</b>	
Mark Band 1 (0–14 marks)	<p>Either an operational performance test or a material analysis should be carried out in a virtual environment. Up to 4 marks can be awarded for successfully using the software and achieving recordable results. Up to 2 marks can be awarded for the presentation of results in an appropriate format and suitable for future analysis</p> <p>To gain the marks from mark band 2, learners should refer back to the design specification for the product or material being analysed and evaluate the results of their simulation against it in order to establish whether there is conformity. Up to 2 marks can be awarded for analysis of the results and up to 2 marks can be awarded for the comparison with the specification.</p> <p>Marks are available for learners who know about the higher levels of the software capabilities to explain strategies used to resolve issues of non-compliance, for example by changing parameters and adopting a ‘what if’ scenario. The learner should explain how the analysed results could be used to instigate design modifications in the case of non-compliance with specification. Up to 4 marks can be awarded for the explanation of the strategy and should be based on how well the suggestions will ensure the product/system/material moves into compliance.</p>

## Approaches to assessment

It may be appropriate to devise four tasks for the assessment of this unit.

Task 1 could be set to cover assessment foci 1 and 2 and may be an investigative task requiring learners to look at both computer systems and specific software packages. Learners will need to look at a basic computer system, naming parts, their function and inter relationships. To move up to mark band 3 learners must explain their reasons and develop their ideas to encompass data storage, with reasoning given for each method of data storage, the advantages and disadvantages. The second part of the task could be focused around specific software applications and the requirement to produce a case study around an engineered product. For example, the development and design of a modern car would encompass the requirements of band 3. As such, the evidence for this task would need to be submitted in a 'report'.

Task 2 could focus on using CAD software to produce 2D drawings to meet the requirements of assessment focus 3. For band 1, the learner must produce one component detail drawing and one assembly drawing. Drawings should be in orthographic projection and must be correctly drawn and represented. For band 2, the drawings should be redrawn using pictorial projections. To achieve mark band 3, the two drawings must contain circuit and system symbols to British Standards. All the evidence for this task will need to be in the form of a 'process portfolio'.

Task 3 could be about using design software to produce 3D models meeting the requirements of assessment focus 4. For mark band 1 the drawings need only be simple wire frame and wire frame with hidden line removal type drawings. For higher mark bands the drawings should be manipulated and be usable as presentation type drawings. Evidence of manipulative skills will require capturing with screen dumps and learner observation record sheets. As such, the evidence would need to be submitted in a 'process portfolio'.

Task 4 could be a practical activity based on the testing and analysis simulation software used to investigate the performance of a product/system/material which meets the requirements of assessment focus 5. The task must give learners the opportunity to move up the mark bands by using a band one activity based on a virtual environment involving a real engineered product, system or structure which is sufficiently complex to produce a range of results which can be evaluated against its design specification. The task will test the learner's competence in using simulation software but to achieve marks in the higher bands they will be need to present evidence that shows that they understand why simulation is a much better option than 'cutting expensive metal' or building a scale model of a structure, for example when proving the design of a new a product or system. As such the evidence would need to be submitted in a 'process portfolio' and for the higher mark band a 'report'.

## Guidance for teaching this unit

### Delivery guidance

This unit is 60 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 20 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

As the purpose of the unit is to create an enthusiasm for design engineering, wherever possible teaching should reflect work typically carried out in industry, preferably with a local bias. Also, it must not be forgotten that the unit is 60 GLH which would leave little time available for consolidating newly acquired skills by completing non-assessed work tasks.

The unit is designed to give learners an insight into the ever-increasing role of computers within the design and pre-production phases of the production process. While this will require a certain amount of research, greater emphasis should be placed upon the practical, hands-on skills required to use different types of software package. For those working at mark band 3, the amount of guidance given after initial introduction to the software used, particularly when producing assessment materials, should be limited.

It is important that learners have the opportunity to sample all of the types of software listed in the learning outcomes. The mark bands have been designed to ensure that a learner doing this, even if the software is used on only a fairly basic level, will achieve at least mark band 1.

Where possible, learners should emphasise the presentation aspects of the various software packages, and should be encouraged to produce a portfolio of their work during the teaching and formative assessment stages of delivery. This could be a valuable tool in creating and maintaining the interest and enthusiasm intended of the unit and be of use as they progress towards work or higher education.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	<p>Identifying and using the information from a variety of sources.</p> <p>Identifying the component parts of a typical computer system, giving a basic description of their functions, roles and relationships within the system. Assessment focus 1.</p> <p>Exploring and stating the capabilities of commercially available software selected for the purpose of design, presentation, testing and analysis and giving examples of their use in engineering. Assessment focus 2.</p>
<b>Creative thinkers</b>	<p>Design software offers a number of different ways of achieving the design criteria. The creative thinker reasons the most appropriate route to achieving the requirements.</p> <p>Producing 2D CAD working drawings of engineered assemblies and components in orthographic projection and to British Standard. Assessment focus 3.</p> <p>Producing a 3D representation of a component that requires the drawing, surfaces and model to be defined by methods other than extrusion of 2D shapes and manipulating the model to display different orientations of the component. Assessment focus 4.</p> <p>Conducting a virtual operational performance test or material analysis of selected product or material for a given purpose and presenting the results for analysis. Assessment focus 5.</p>
<b>Reflective learners</b>	<p>Goals and targets need to be set if the assignments are to be completed successfully and the ability to review progress and make adjustments where necessary requires this skill.</p>
<b>Team workers</b>	<p>Not present in this unit.</p>
<b>Self-managers</b>	<p>Technical software requires a disciplined and structured approach to successful completion of the task in hand. Ensuring that assignments are completed to a timescale also requires this skill.</p> <p>Producing 2D CAD working drawings of engineered assemblies and components in orthographic projection and to British Standard. Assessment focus 3.</p> <p>Producing representations of simple 3D components as wire frame drawings, simple wire frame with hidden line removal for use as data or as 3D models. Assessment focus 4.</p> <p>Conducting a virtual operational performance test or material analysis of selected product or material for a given purpose. Presenting the results for analysis. Assessment focus 5.</p>

Skill	When learners are ...
<b>Effective participators</b>	Producing representations of simple 3D components as wire frame drawings, simple wire frame with hidden line removal for use as data or as 3D models. Assessment focus 4.  Conducting a virtual operational performance test or material analysis of selected product or material for a given purpose. Presenting the results for analysis. Assessment focus 5.

## Functional skills – Level 2

This unit provides opportunities to develop functional skills in English, particularly when learners are comparing, selecting and reading texts and using information sources to select program features for a given purpose. The unit also has opportunities for the development of functional skills in mathematics, particularly when using appropriate mathematical procedures to find results and solutions when calculating dimensions, scales and drawing ratios.

The unit particularly provides opportunities for the development of ICT. Learners will have to understand storage and security of ICT systems, select and use appropriate software applications and consider the engineering applications of the software. They will develop a range of drawings in both 2D and 3D and will build up layers using aspects of the software and recording the stages. They will use software packages to virtually test and prove designs.

### Work experience

This unit would be ideal for some level of work placement as it would be of huge benefit for learners to see the use of computers and associated software within the design and pre-production process in an industrial situation. If work placements are available, assignments based around the placement would be beneficial and are encouraged. However, it is appreciated that suitable placements are not always available, and in-house assignments are acceptable as a means of assessment.

### Specialist resources

Centres will require access to:

- computer systems of suitable high processing specification
- suitable 2D and 3D design software and training publications
- testing and analysis software
- presentation software
- internet access.

# Unit 3: Selection and Application of Engineering Materials

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**Principal Learning unit**

**Level 3**

**Guided Learning Hours: 60**

**Internally assessed**

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## **About this unit**

Materials technology has developed at a rapid pace over the last century. This continues with the demand for better and more durable materials for the aerospace, electronics, automotive and other industrial sectors. There is also an increasing need for domestic and consumer products to be more efficient and environmentally friendly.

Design and manufacturing engineers need to know about the range of materials available for engineered products. Engineers also need to know about information sources, so that they can check the availability and cost of materials and how they can best be processed.

Maintenance engineers need to know how the component parts of plant and machinery are affected by their service conditions and how they may be protected against wear and corrosion. When a component fails in service, engineers must be able to understand why this has happened. A change of design, or a change to a more suitable material can then be made to reduce the risk future failure.

In this unit you will find out about the structure of materials, their properties and forms of supply. You will get to know about the effects of processing and also the ways in which materials can sometimes fail in service. Information on materials is available from a number of sources and you will be introduced to some of these so that you can make selections for given purposes.

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## Learning outcomes

On completion of this unit, a learner should:

- LO.1. Know about the structure and their effects on the mechanical properties of engineering materials
  - LO.2. Know about the forms of supply, applications and the selection of engineering materials
  - LO.3. Know about the impact of processing on the structure of engineering materials
  - LO.4. Know about the effects of loading, modes of failure and carry out testing of engineering materials.
-

## What you need to cover

- LO.1 Know about the structure and their effects on the mechanical properties of engineering materials**
- Learners will need to find out about the structure of engineering materials, eg atomic structure, periodicity, electrovalent bonds, covalent bonds, metallic bonds, allotropy, crystal lattice structure, polymer structure.
- Learners will investigate the mechanical properties and durability of engineering materials, eg strength, hardness, toughness, brittleness, malleability, ductility, corrosion resistance, resistance to environmental degradation.
- They will also look at the thermal properties of engineering materials, eg thermal conductivity, linear expansivity; and their electrical and magnetic properties, eg resistivity, permeability, permittivity.
- LO.2 Know about the forms of supply, applications and the selection of engineering materials**
- Learners will need to find out about the classification and application of engineering materials, eg ferrous metals (cast irons, plain carbon steels, alloy steels), non-ferrous metals (copper, tin, lead, zinc, aluminium, titanium, brasses, bronzes, solders, aluminium alloys), thermoplastics, thermosetting plastics, composites, smart materials (piezoelectric, thermo-responsive, electro/magneto restrictive, pH sensitive).
- Learners will need to know about the forms of supply of engineering materials, eg barstock, tube, wire, rolled sections, plate sheet, castings, forgings, mouldings extrusions, raw materials for polymers.
- Learners will also need to be familiar with information sources used for the selection of engineering materials, eg manufacturers' data sheets, CD-ROM databases, internet databases.
- LO.3 Know about the impact of processing on the structure of engineering materials**
- Learners will need to find out about the impact of cold and hot working on engineering materials, eg cold working (work hardening), hot working (grain flow, grain growth, glass transition temperature).
- Learners will also need to know about the impact of heat treatment on engineering materials, eg annealing normalising, hardening and tempering of plain carbon steels, case hardening, precipitation hardening of aluminium alloys.
- LO.4 Know about the effects of loading, modes of failure and carry out testing of engineering materials**
- Learners will need to investigate the loading of engineering materials, eg direct and shear stress and strain, modulus of elasticity, shear modulus, ultimate tensile strength, shear strength, factor of safety.
- Learners' investigations should also include the modes of failure on engineering materials, eg elastic failure, ductile failure, brittle fracture, fatigue, creep.
- Learners will need to carry out testing of engineering materials to help them know about different effects, eg destructive testing (tensile and compressive tests, impact tests, fatigue tests, creep tests), non-destructive testing (indentation tests, dye penetrant tests, ultrasonic tests, x-ray tests), safe use of equipment.

## How you will be assessed

This unit focuses on the selection and applications of engineering materials. As such, you will be assessed through an assignment giving opportunities to demonstrate what you know about the structures and properties of engineering materials, their forms of supply, their applications and selection, the impact of processing on materials and the loading, modes of failure and testing of engineering materials. The theme of this assignment will be selecting and applying materials within the world of engineering.

This unit will be assessed by your tutor. You are likely to be given a number of tasks that will cover all of the material you have studied. Your tutor will give you opportunities to develop evidence and one or more tasks could be set in the laboratory or workshop, and may relate to your work experience. These opportunities might typically consist of four tasks.

Task 1 could cover the requirements of assessment foci 1, 2.1 and 2.2 with written activities on the structure, properties and applications of engineering materials. All of the evidence for this task will need to be in the form of a 'report'.

The second task could cover the requirements of assessment foci 3.1 and 3.2, with written activities on the effects of material processing and heat treatment. Again all of the evidence for this task will need to be submitted in the form of a 'report'.

Task 3 could cover the requirements of assessment foci 4.1 and 4.2 with written activities involving calculations concerned with material loading and modes of failure. Again all of the evidence for this task will need to be submitted in the form of a 'report'.

The final task could be a practical exercise on material testing and the analysis of test data and addressing assessment focus 4.3. This could be carried out in a laboratory setting or on an appropriate work placement. As this task would involve some practical elements all of the evidence for this task will need to be in the form of a 'process portfolio'.

## Marking grid

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.1</b> <b>Know about the structure and their effects on the mechanical properties of engineering materials</b>	Describes crystal lattice and polymer structures and their effect on the mechanical properties of metals and plastics.  (0–4)	Describes crystal lattice and polymer structures and their effect on the mechanical and electrical properties of metals and plastics.  (5–6)	Describes crystal lattice and polymer structures and their effect on the mechanical, electrical and thermal properties of metals and plastics.  (7–8)	8
<b>LO.2.1</b> <b>Forms of supply and applications</b>	Describes a form of supply and an application of a given metal, a given polymer and a given composite material.  (0–3)	Describes the properties, a form of supply and an application of a given metal, a given polymer and a given composite material.  (4–6)	Justifies an application of a given metal, a given polymer and a given composite material in terms of the material properties and form of supply.  (7–9)	9
<b>LO.2.2</b> <b>Information sources and material selection</b>	Uses a given information source to select material for a given purpose.  (0–3)	Selects an information source and uses it to select material for a given purpose.  (4–5)	Selects an information source and justifies its use to select material for a given purpose.  (6–7)	7

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.3.1 Impact of processing</b>	Describes the occurrence of work hardening and grain growth in metals and the glass transition temperature in polymers.  (0–3)	Describes the change in the properties of metals due to the occurrence of work hardening and grain growth and due to the occurrence of the glass transition temperature in polymers.  (4–5)	Describes the change in the properties of metals due to the occurrence of work hardening and grain growth, and the change in properties of polymers due to the occurrence of the glass transition temperature making reference to the micro-structure of the materials.  (6–7)	7
<b>LO. 3.2 Heat treatment</b>	Distinguishes between annealing, quench hardening and tempering, case hardening and precipitation hardening of materials.  (0–4)	Distinguishes between annealing, quench hardening and tempering, case hardening and precipitation hardening processes stating the materials to which they are applicable and property changes that occur.  (5–6)	Distinguishes between annealing, quench hardening, tempering, case hardening and precipitation hardening processes stating the materials to which they are applicable, the property changes that occur and the structural changes that take place during the processes.  (7–8)	8
<b>LO.4.1 Mechanical loading</b>	Calculates direct stress, factor of safety and shear stress in given loaded materials.  (0–3)	Calculates direct stress and strain, factor of safety and shear stress and strain in given loaded materials.  (4–5)	Calculates direct stress and strain, factor of safety, shear stress and strain, modulus of elasticity and shear modulus of given loaded material.  (6–7)	7

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.4.2 Modes of failure</b>	Describes three modes of failure that can occur in engineering materials.  (0–3)	Describe three modes of failure that can occur in engineering materials and the service conditions under which two of them are likely to happen.  (4–5)	Describe three modes of failure that can occur in engineering materials, the service conditions under which two of them are likely to happen and the characteristic appearance of the two failure modes.  (6–7)	7
<b>LO.4.3 Material testing</b>	Carries out a destructive and a non-destructive material test and record the test data.  (0–3)	Carries out a destructive and a non-destructive material test and analyses the test data to verify the material properties or nature of faults.  (4–5)	Carries out a destructive and a non-destructive material test, analyses the test data to verify the material properties or nature of faults and describes industrial settings where such tests would be routine.  (6–7)	7
<b>Total marks</b>				<b>60</b>

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to confirm marks within the objective approach. The guidance can be used to allocate specific marks for that band.

<b>Assessment focus LO.1</b>	
Mark Band 1–3 (0–8 marks)	<p>1 mark can be awarded for describing each of (i) bcc, (ii) fcc and (iii) cph crystal lattice structures and (iv) the structure of polymers together with associated mechanical properties.</p> <p>Up to 2 marks can be awarded for describing the effects of structure on the electrical properties of metals and plastics.</p> <p>Up to 2 marks can be awarded for describing the effects of structure on the thermal properties of metals and plastics.</p>

<b>Assessment focus LO.2.1</b>	
Mark Band 1–3 (0–9 marks)	<p>1 mark each can be awarded for describing a form of supply and application of each of the three given materials, eg given metal, polymer and composite.</p> <p>1 mark each can be awarded for describing the properties of each of the three given material.</p> <p>Up to 2 marks can be awarded for justifying the application of the given materials in terms of their properties and forms of supply. Both properties and forms of supply should be linked to the application to get both marks.</p>

<b>Assessment focus LO.2.2</b>	
Mark Band 1–3 (0–7 marks)	<p>Up to 3 marks can be awarded for using a given information source to select a material for a given purpose. The selection of the material should mean that it would be able to function in line with the given purpose and the references back to the information source should clearly demonstrate this.</p> <p>Up to 2 marks can be awarded for selecting and using an appropriate information source. The marks should be awarded based on its ability to give the data required for the given purpose. Marks are form the correct selection.</p> <p>Up to 2 marks can be awarded for justifying the selection of an appropriate information source in terms of accessibility, ease of use and the range and depth of information provided.</p>

<b>Assessment focus LO.3.1</b>	
Mark Band 1–3 (0–7 marks)	<p>1 mark can be awarded for each response describing the occurrence of work hardening and grain growth in metals and the glass transition temperature in polymers.</p> <p>1 mark can be awarded for describing the change in the properties of metals due to the occurrence of work hardening and grain growth and 1 mark for describing the change in the properties in polymers due to the occurrence of the glass transition temperature.</p> <p>Up to 2 marks can be awarded for making reference to the micro-structure of the materials during the descriptions relating to changes in properties.</p>

<b>Assessment focus LO.3.2</b>	
Mark Band 1–3 (0–8 marks)	<p>Up to 4 marks can be awarded for distinguishing between the given heat treatments.</p> <p>Up to 2 marks can be awarded for stating the materials for which the given processes are applicable and the property changes that occur.</p> <p>Up to 2 marks can be awarded for describing the structural changes that take place during the given processes.</p>

<b>Assessment focus LO.4.1</b>	
Mark Band 1–3 (0–7 marks)	<p>1 mark can be awarded for calculating each of direct stress, factor of safety and shear stress in given loaded materials.</p> <p>1 mark can be awarded for calculating each of direct and shear strain.</p> <p>1 mark can be awarded for calculating each of modulus of elasticity and shear modulus.</p>

<b>Assessment focus LO.4.2</b>	
Mark Band 1–3 (0–7 marks)	<p>1 mark each can be awarded for describing three modes of failure.</p> <p>1 mark each can be awarded for describing the conditions under which two of the modes of failure are likely to happen.</p> <p>Up to 2 marks can be awarded for describing the characteristics of the failure modes. This response should indicate how a failure might become visible before and during the failure.</p>

<b>Assessment focus LO.4.3</b>	
Mark Band 1–3 (0–7 marks)	<p>Up to 3 marks can be awarded for carrying out a destructive, a non-destructive test and recording the test data. This should be based on the tests being carried out effectively and safely and the data recorded being able to be understood by a third party.</p> <p>Up to 2 marks can be awarded for analysing the test data to determine and verify the material properties or the nature of faults.</p> <p>Up to 2 marks can be awarded for describing the industrial settings where the tests would be routinely carried out.</p>

## Approaches to assessment

It may be best to devise four tasks for the assessment of this unit.

Task 1 could cover the requirements of assessment foci 1 and 2.1 and 2.2 with written activities. Learners could be asked to describe, with the aid of diagrams, the crystal lattice structures commonly found in metals and also give a general description of polymer structures. These could be accompanied by a description of their effects on the mechanical, electrical and thermal properties of metals and plastics for assessment focus 1.

An activity could also be set which requires learners to justify the application of materials for selected purposes in terms of the material properties and forms of supply for assessment focus 2.1. A final activity would require learners to select an information source and justify its use in terms of its accessibility, breadth and depth of information contained and user friendliness in selecting a material for a given purpose to address assessment focus 2.2. All of the evidence for this task will need to be in the form of a 'report'.

Task 2 could link assessment foci 3.1 and 3.2 with written activities. To address the requirements of focus 3.1 learners could be asked to describe the change in the properties of metals due to cold working and hot working. The effects of cold working should include a description of the structural deformation that leads to work hardening. The effects of hot working should make mention of allotropic change, grain flow and grain growth. Learners could also be asked to describe the change in the properties of thermoplastics due to the occurrence of the glass transition temperature. To address the requirements of assessment focus 3.2, learners could be asked to describe the range of heat treatment processes, the materials to which they are applicable and the associated structural and property changes. Throughout the task, reference should be made to the micro-structure of the materials accompanied by suitable diagrams and sketches. All of the evidence for this task will need to be in the form of a 'report'.

Task 3 could link assessment foci 4.1 and 4.2 with written activities including calculations. To address the requirements of focus 4.1, learners could be asked to calculate the direct and shear stress in loaded engineering components and factor of safety in operation. They could also be asked to calculate direct and shear strain from given data and the elastic moduli of the materials. The calculations should be realistic and apply to typical engineering materials in a service environment. To address the requirements of assessment focus 4.2 learners could be asked to describe three different modes of failure that can occur in engineering materials and the service conditions under which two of them are likely to occur. The descriptions should be accompanied by sketches to illustrate the characteristic appearance of the material in the locality of the failure. All of the evidence for this task will need to be in the form of a 'report'.

Task 4 could address the requirements of assessment focus 4.3 and should require the learner to carry out a destructive and a non-destructive material test. It is likely that the evidence would include a learner observation record sheet supplemented by annotated photographs for this part of the task. Learners could be asked to submit test outcomes containing a record and analyse the test results to verify the properties or condition of the materials. They could also be asked to describe typical industrial situations where such tests would be routinely carried out. All of the evidence for this task will need to be in the form of a 'process portfolio'.

## Guidance for teaching this unit

### Delivery guidance

This unit is 60 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 20 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

The learning outcomes can be delivered and assessed in order. It is important that learners should first be introduced to the atomic structure of materials and the concepts of periodicity and bonding. The use of unit cell models will be useful in explaining crystal lattice structure, particularly when distinguishing between face-centred cubic (fcc) and close-packed hexagonal (cph) structures. The structure of interstitial and substitutional alloys can then be explained. Learners should be aware that other crystal lattice structures naturally exist in non-metallic substances and that some elements, such as iron and carbon, are allotropic.

Learners should be aware that carbon and hydrogen are two of the main constituents of polymers. The chain structures of polyethylene (polythene), polypropylene and polystyrene could be given as examples. The occurrence of the glass transition temperature in thermoplastics and cross-linking in thermosetting plastics should be explained and their effects described.

This knowledge will underpin an understanding of material properties. The ranged properties should be clearly defined and related to the structure of materials. Delivery might be reinforced by video footage and in particular, items from the BBC Craft Studies and Technical Studies series will be of value. Learners can then be introduced to the range of engineering materials, their properties, forming processes, applications and forms of supply.

A range of material specimens will be essential and practical activities could include visual and tactile examination, such as observing granular structure or detecting the presence of free graphite in cast iron. If facilities exist they could also include the micro-examination of polished and etched specimens viewed through a metallurgical microscope. Some of the more common fibre reinforced and laminated composite materials should be introduced together with a range of the more recently introduced smart materials and their applications. Learners should be introduced to a range of information sources that are useful for material selection, and internet access will be of value. Some useful websites are listed ahead under the ‘specialist resources’ heading.

Learning outcome 3 deals with the effects of forming and shaping processes and the effects of heat treatment. The occurrence of work hardness due to plastic deformation in cold working processes such as cold drawing, rolling and pressing should be explained. A qualitative treatment of hot working processes, such as forging, hot rolling and casting should be accompanied by an explanation of property change with temperature and the effects of grain growth and grain flow on material strength. The relevance of the glass transition temperature to hot forming processes such as the injection moulding and vacuum forming of thermoplastics should be explained.

When considering heat treatment processes it should be explained that annealing/normalising can be carried out on non-metals, particularly on glass, to relieve internal stresses. The relevant part of the iron-carbon thermal equilibrium diagram should be introduced when describing the annealing, normalising and quench hardening of plain carbon steels. Similarly, the relevant part of the aluminium-copper thermal equilibrium diagram can be used to illustrate the precipitation hardening of duralumin-type aluminium alloys. The carburising process for low carbon steel using solid, liquid and gaseous carbon-bearing media should be explained together with the secondary processes to refine the core and harden the carbon-enriched case of the material.

The final learning outcome is concerned with the loading of materials within their elastic range, the modes of failure that might be encountered and test procedures that are used to verify the properties of engineering materials or to detect material flaws and faults. The explanation of direct and shear stress and strain, factor of safety and elastic moduli should be accompanied by the tutor-led solution of problems. Learners should be made aware that calculated values of stress may be exceeded in practice due to the presence of stress concentrations at the points of loading, holes and internal corners etc.

When considering modes of failure, it should be explained that failure does not necessarily mean that a material has fractured. Permanent deformation caused by exceeding the elastic limit of a material may be classed as failure. Learners should be aware that factor of safety may be calculated against the ultimate strength of a material or against its elastic limit stress. If available, it will be useful to present specimen components for learners to inspect when explaining the occurrence of ductile fracture, brittle fracture, fatigue and creep failure.

Learners should be familiar with the range of material tests that are routinely carried out in engineering and given the opportunity to carry out a destructive and a non-destructive test from the range. The tests should be carried out using industrial standard equipment in an approved manner and making full use of personal protective equipment. Some instruction in technical report writing may be appropriate to ensure that learners present their recorded data, analysis and findings in a logical way.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	<p>Identifying coursework questions and problems to resolve.</p> <p>Describing crystal lattice and polymer structures and their effect on the mechanical properties of metals and plastics. Assessment focus 1.</p> <p>Describing a form of supply and an application of a given metal a given polymer and a given composite material. Assessment focus 2.1.</p> <p>Using a given information source to select material for a given purpose. Assessment focus 2.2.</p> <p>Describing the occurrence of work hardening and grain growth in metals and the glass transition temperature in polymers. Assessment focus 3.1.</p> <p>Distinguishing between annealing, quench hardening and tempering, case hardening and precipitation hardening of materials. Assessment focus 3.2.</p> <p>Calculating direct stress, factor of safety and shear stress in given loaded materials. Assessment focus 4.1.</p> <p>Describing three modes of failure that can occur in engineering materials. Assessment focus 4.2.</p> <p>Carrying out a destructive and a non-destructive material test and record the test data. Assessment focus 4.3.</p>
<b>Creative thinkers</b>	Using information sources to select a material for a given purpose.
<b>Reflective learners</b>	<p>Setting goals for the development of each of their assignments.</p> <p>Reviewing their progress against the completion of their assignments.</p> <p>Using mathematics to analyse test data and calculate factor of safety.</p>
<b>Team workers</b>	Not present in this unit.
<b>Self-managers</b>	<p>Planning and organising the creation of their assignments for this unit.</p> <p>Dealing with time pressures and deadlines for the production of their assignments.</p> <p>Seeking advice and support from their peers and tutors when needed.</p> <p>Calculating direct stress, factor of safety and shear stress in given loaded materials. Assessment focus 4.1.</p> <p>Carrying out a destructive and a non-destructive material test and record the test data. Assessment focus 4.3.</p>

<b>Effective participators</b>	Carrying out a destructive and a non-destructive material test and record the test data. Assessment focus 4.3.
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## Functional skills – Level 2

This unit provides opportunities to develop functional skills in English, particularly when comparing, selecting and reading texts and using information sources to select materials for a given purpose.

Learners will also have opportunities to develop functional skills in mathematics when using appropriate mathematical procedures and finding results and solutions when calculating stress, strain and factor of safety.

### Work experience

Evidence for this unit could be gathered during an appropriate work placement. Participating in the assembly or dismantling of engineered products, inspection of components and material test procedures can help reinforce the delivery of the unit.

### Specialist resources

Learners should have access to a wide range of material specimens and failed components for visual and tactile inspection. The availability of metallurgical microscopes and a range of polished and etched specimens would be an additional advantage. Access to industrial standard test equipment is necessary for assessment focus 3.4.3. Learners should have access to a range of material information sources such as manufacturers' data sheets, relevant British Standards, CDR and the internet.

The following websites give free access to material selection data:

- [www.avestapolarit.com](http://www.avestapolarit.com)
- [www.copper.org](http://www.copper.org)
- [www.matweb.com](http://www.matweb.com)
- [www.plaspec.com](http://www.plaspec.com)
- [www.sandvik.com](http://www.sandvik.com)
- [www.steelforge.com](http://www.steelforge.com)
- [www.structural-engineering.fsnet.co.uk](http://www.structural-engineering.fsnet.co.uk)

The BBC Engineering Craft Studies and Technical Studies range of videos will provide a useful reinforcement to delivery. These are available from:

BBC Videos for Education and Training

Woodlands

80 Wood Lane

London W12 0TT

Telephone: 020 8576 2541

**Reference material**

Darbyshire A – *Mechanical Engineering – BTEC Optional Units* (Newnes, 2003)  
ISBN 0750657618

Higgins R – *Materials for Engineers and Technicians* (Newnes, 2006) ISBN 0750668504

Timings R L – *Engineering Materials, Volume 1* (Longman, 1998) ISBN 0582319285

Timings R L – *Engineering Materials, Volume 2* (Longman, 2000) ISBN 0582404665



## Unit 4: Instrumentation and Control Engineering

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Principal Learning unit

Level 3

Guided Learning Hours: 60

Internally assessed

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### About this unit

Have you ever wondered how a robot puts together the parts of a car or how the cruise control works on a car? In common with many items, these are just two examples of control systems.

This unit will provide you with the opportunities to learn about and apply the underpinning theory behind control systems. It will also enable you to investigate the principal elements and components within instrumentation and control engineering systems including the mathematical principles required for the design and implementation of a simple control system. The topic will help you develop an understanding of instrumentation and control applications in a range of applications such as, industry, the home, the automobile and examine its impact on the environment and everyday life.

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### Learning outcomes

On completion of this unit, a learner should:

- LO.1. Understand the difference between analogue and digital signals and the need for various forms of transmission media
  - LO.2. Know about the use of sensors, transducers and instrumentation displays in instrumentation and control applications
  - LO.3. Understand the principles and difference between open loop and closed loop systems
  - LO.4. Understand the use of programmable logic controllers in instrumentation and control applications
  - LO.5. Understand applications of control engineering.
-

## What you need to cover

- LO.1 Understand the difference between analogue and digital signals and the need for various forms of transmission media**
- Learners will need to know about the differences between analogue and digital signals and the relative advantages and disadvantages of each. They will need to learn the different ways of transmitting signals including pneumatic, hydraulic, electrical, radio and optical.
- Learners will discover that data is transmitted in either serial or parallel form and that there are various protocols that allow systems to talk to each other such as RS423, IEEE, USB, Field bus, Profibus (Process Field Bus), CAN (Controller Area Network), LIN (Local Interconnect Network), and RFID (Radio frequency identification). They will also learn that multiplexers can be used to put information into different time or frequency slots so that it cuts down on the use of cables or optical fibres.
- Learners will find out about signal conditioners, converting analogue to digital and digital to analogue and the use of operational amplifiers. They will also need to know about characteristics and properties of different types of transmission, eg data format, data rate, bandwidth, error correction.
- LO.2 Know about the use of sensors, transducers and instrumentation displays in instrumentation and control applications**
- Learners will need to understand the use of sensors such as moiré fringe, incremental and absolute encoders, proximity, micro, magnetic reed, float switches, passive infra red and transducers for temperature, position, displacement, pressure, level, velocity, flow and light and how they are used in instrumentation and control systems.
- Learners will identify various actuators, including electric motors, relays, solenoids, hydraulic and pneumatic cylinders, diaphragms and rams. They will also identify different display devices, eg cathode ray tube (CRT), light emitting diode (LED), liquid crystal display (LCD), 7 segment, starburst, analogue meters.
- LO.3 Understand the principles and difference between open loop and closed loop systems**
- Learners will need to find out about control systems, including the differences between open and closed loop, the fact that feed-forward incorporates prediction in a closed loop system and that feedback can be positive or negative and the effects of both in a closed loop system. They will also understand the terms applied to closed loop system such as gain, hysteresis, signal processing and conditioning, damping, overshoot, settling time, hunting, stability and instability, disturbances and rejection, compensation, input, output, set point, demand value, error and steady state error.
- Learners will work with more complex closed loop systems such as those involving PID (proportional/integral/derivative) control and learn that the proportional element handles the immediate error, the integral learns from the past and the derivative anticipates the future.

<b>LO.4 Understand the use of programmable logic controllers in instrumentation and control applications</b>	<p>Learners will need to find out about and program programmable logic controllers (PLCs), which are specialised computers that control automation processes by reading the inputs from sensors and transducers and controlling actuators.</p> <p>Learners will be introduced to the basic concept of the PLC and also to some possible alternatives, eg PICs (peripheral interface controller) and microcontrollers, and understand the relative advantages, eg rugged construction suitable for harsh industrial environments, simple programming, modular construction, easily expandable, easily reconfigurable. They will also need to know about the disadvantages, eg relatively high cost compared with other solutions (such as PC-based controllers), components and modules not interchangeable between manufacturers, operation limited to less sophisticated applications, not suitable for high-speed control applications.</p> <p>Learners will investigate system components, eg microcontroller as a programmable controller remote or hand-held programmer digital output via relays (either electromagnetic or solid-state), digital input via optical isolators, analogue input via analogue to digital converter (ADC), analogue output via digital to analogue converter (DAC), modular rack.</p>
<b>LO.5 Understand applications of control engineering</b>	<p>Learners will need to investigate an application of control engineering. Examples might include washing machines, DVD (digital versatile disk) drives, satellite antenna steering systems, motorcar engine or braking systems, CNC (computer numerical control) machines or robots.</p> <p>Learners will need to find out how to represent an application of a control system by the use of a block diagram, eg labelled inputs, labelled outputs, energy sources, controller, additional signal conditioning (amplification, filtering, etc). They will also need to know about types of sensors, transducers, actuators and displays, eg a temperature sensor such as a thermocouple or semiconductor temperature sensor, a position sensor such as a linear or rotary potentiometer or linear variable differential transducer (LVDT), an angular speed sensor such as a tachogenerator, an optical shaft encoder, a DC motor, a stepper motor, a relay (either electromechanical or solid-state), an actuator (linear or rotary type), a gearbox, a moving coil meter, (x) an liquid crystal display (LCD), a light emitting diode (LED) display, an LED bar or seven-segment display, a cathode ray tube (CRT) display.</p>

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## How you will be assessed

This unit will focus on instrumentation and control systems and their applications in industry. You will be will be opportunities to investigate instrumentation and control systems of different types and complexity. You will also be able to investigate the sensors, transducers, actuators, displays and how they work together in a practical control engineering system.

This unit will be assessed by your tutor who will set an assignment for you to complete. You are likely to be given one or more tasks that will cover the material you have studied. At least some of these tasks will be set in the workshop and may relate to your work experience. Your tutor will give you opportunities to develop evidence. These opportunities could typically consist of five tasks.

Task 1 could cover assessment focus 1 and could involve you carrying out an investigation of signals and transmission media. Your evidence is likely to be in the form of a 'report'.

A second task could cover 2, and could be based on an investigation of a variety of different types of sensor, transducer and display. Evidence for this task is likely to be in the form of a 'report'.

Task 3 could cover 3 and would involve you carrying out an investigation of open and closed loop control systems. Evidence is again likely to be in a written 'report' format.

Task 4 could cover assessment focus 4 and will need you to carry out practical activities using simulation software. Because of the practical nature of this task your evidence is likely to be in the form of a 'process portfolio'.

A fifth task to cover 5 could be based on an investigation of a complete application of a control engineering system. Evidence would be in the form of a 'report'.

## Marking grid

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.1</b> <b>Understand the difference between analogue and digital signals and the need for various forms of transmission media</b>	Describes the fundamental characteristics of analogue and digital signals and explains the need for the different types of transmission media.  (0–5)	Describes the fundamental characteristics of analogue and digital signals, explains the need for the different types of transmission media and explains the methods of connecting and interfacing analogue and digital signals taking into account their characteristics and the properties of different types of transmission media.  (6–9)	Describes the fundamental characteristics of analogue and digital signals, explains the need for the different types of transmission media, explains different methods of connecting and interfacing analogue and digital signals taking into account their characteristics and the properties of different types of transmission media and explains the process of signal conversion from analogue to digital, digital to analogue, serial to parallel and parallel to serial.  (10–13)	13
<b>LO.2</b> <b>Know about the use of sensors, transducers and displays in instrumentation and control applications</b>	Describes instrumentation and control systems and explains the role of digital and analogue sensors, transducers and displays in instrumentation and control applications.  (0–4)	Describes instrumentation and control systems and explains the role and operation of digital and analogue sensors, transducers and displays in instrumentation and control applications.  (5–7)	Describes instrumentation and control systems and explains the role and operation of digital and analogue sensors, transducers and displays in instrumentation and control applications and evaluates a complete instrumentation and control system and explains the process of code conversion and display technology (as appropriate to the system).  (8–10)	10

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.3</b> Understand the principles and difference between open loop and closed loop systems	Describes the principles of open loop and closed loop control.  (0–4)	Describes the principles of open loop and closed loop control and explains the simplified arrangement of a practical closed loop control system, differentiating between positive and negative feedback and feed-forward.  (5–7)	Describes the principles of open loop and closed loop control, explains the simplified arrangement of a practical closed loop control system, differentiates between positive and negative feedback and feed-forward and evaluates the operation of a complete control system that incorporates proportional, integral and derivative control.  (8–10)	10
<b>LO.4</b> Understand the use of programmable logic controllers in instrumentation and control applications	Describes a PLC system and explains its advantages and disadvantages.  (0–4)	Describes a PLC system and explains its advantages, disadvantages and operation and programs it to carry out a single specified task.  (5–7)	Describes a PLC system, explains its advantages, disadvantages and operation, programs it to carry out a single specified task and evaluates the operation of a typical industrial application of a PLC system and its associated control program.  (8–10)	10

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.5</b> <b>Understand the applications of control engineering</b>	Describes an application of control engineering and draws a block diagram of the system, indicating the types of sensors, transducers, actuators and displays.  (0–7)	Describes an application of control engineering, draws a block diagram of the system, indicates the types and roles of sensors, transducers, actuators, signal conditioning, displays and control program used.  (8–13)	Describes and evaluates an application of control engineering, draws a block diagram of the system, indicates and justifies the types and roles of sensors, transducers, actuators, signal conditioning, displays and control program used.  (14–17)	17
<b>Total marks</b>				<b>60</b>

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to confirm marks within an objective approach. The guidance can then be used to allocate specific marks for that band.

<b>Assessment focus LO.1</b>	
<p>Mark Band 1–3 (0–13 marks)</p>	<p>1 mark can be awarded for describing an analogue signal as one that is continuously variable and 1 mark for describing a digital signal as one that can only exist in one of two discrete levels. Up to 3 marks can be awarded for explaining the need for different types of transmission media. Answers could typically include the use of screened coaxial cables for low-loss, constant impedance connections capable of supporting fast data rates (1 mark), the use of optical fibres for very fast data rates and exceptional noise immunity (1 mark), and the use of short-range wireless links for applications in which physical connections (ie those based on wire conductors or optical fibres) are not possible (1 mark).</p> <p>Up to 2 marks can be awarded for an explanation of the methods of connecting and interfacing analogue and digital signals. Typically an answer could include any two of the following, with 1 mark for each explained up to a maximum of 2 marks: (i) the need for level shifting to remove/adjust DC components, (ii) filtering to remove noise and hum, (iii) analogue to digital conversion, (iv) digital to analogue conversion, and (v) multiplexing. Up to 2 marks can be awarded for reference to characteristics and properties of different types of transmission.</p> <p>1 mark can be awarded for each explanation of the process of signal conversion from analogue to digital (ADC), digital to analogue (DAC), serial to parallel and parallel to serial. In relation to ADC and DAC conversion typically an answer could include any of the following: (i) the use of a binary weighted or R-2R ladder, (ii) comparator-based flash converter, (iii) successive approximation register, (iv) ramp-type converter. In relation to serial to parallel and parallel to serial data conversion, typically an answer could include an explanation of a serial input/parallel output (SIPO) shift register and an explanation of a parallel input/serial output (PISO) shift register. Alternatively, learners could cite the use of a universal shift register with appropriate control logic for changing the mode of operation in order to support serial/parallel load/shift. In either case learners' explanations could be based on an appropriately annotated block diagram in which inputs, outputs, and control signals are clearly labelled.</p>

<b>Assessment focus LO.2</b>	
Mark Band 1–3 (0–10 marks)	<p>1 mark can be awarded for the description of the instrumentation and control systems and 3 marks for the explanation of the role of digital and analogue sensors, transducers and displays. Typically an answer could include an explanation of the purpose (but not the operation) of the following sensors, transducers and displays, up to a maximum of 3 marks and including any three of the following, awarding 1 mark for each explained: (i) a temperature sensor such as a thermocouple or semiconductor temperature sensor, (ii) a position sensor such as a linear or rotary potentiometer or linear variable differential transducer (LVDT), (iii) an angular speed sensor such as a tachogenerator, (iv) an optical shaft encoder, (v) a moving coil meter, (vi) a liquid crystal display (LCD), (vii) a light emitting diode (LED) display, (viii) an LED bar or seven-segment display, (viii) a cathode ray tube (CRT) display. Note that, for mark band 1 learners are not required to explain the operation of the selected transducers, sensors and displays.</p> <p>Up to 3 marks can be awarded for the explanation of the operation of digital and analogue sensors, transducers and displays in instrumentation and control applications. Typically an answer could include an explanation of the operation of the following sensors, transducers and displays, up to a maximum of 3 marks and including any three of the following, awarding 1 mark for each explained: (i) a temperature sensor such as a thermocouple or semiconductor temperature sensor, (ii) a position sensor such as a linear or rotary potentiometer or linear variable differential transducer (LVDT), (iii) an angular speed sensor such as a tachogenerator, (iv) an optical shaft encoder, (v) a moving coil meter, (vi) a liquid crystal display (LCD), (vii) a light emitting diode (LED) display, (viii) an LED bar or seven-segment display, (viii) a cathode ray tube (CRT) display. Note that, for mark band 2 learners are required to explain the principles of operation of the selected transducers, sensors and displays.</p> <p>Up to 3 marks can be awarded for the evaluation of the instrumentation and control system and explanation of the code conversion and display technology used in the system. Typically an answer could include an evaluation of a position control system, temperature control system or speed control system in relation to the required operating parameters such as accuracy (1 mark), resolution (1 mark) and range (1 mark).</p>

<b>Assessment focus LO.3</b>	
Mark Band 1–3 (0–10 marks)	<p>Up to 2 marks can be awarded for the description of open loop control and up to 2 marks for the description of closed loop control. Learners could produce annotated diagrams for each type of system together with a brief written description of each type of system.</p> <p>Up to 3 marks can be awarded for the explanation of a practical closed loop control system differentiating between negative and positive feedback and feed forward. Typically 1 mark can be awarded for the explanation of system operation (typically mentioning the use of negative feedback and the formation of an error signal) and up to 2 marks for explaining that negative feedback produces an error signal which is the difference between the output (controlled variable) and the input (set point) and thus has the effect of regulating/stabilising the output of a control system by and that positive feedback produces an error signal that is the sum of the output (controlled variable) and the input (set point) and thus produces instability and oscillation.</p> <p>Up to 3 marks can be awarded for an evaluation of the operation of a complete control system that incorporates proportional, integral and derivative control. Typically an answer could include an evaluation of a position control system or speed control system in relation to the required operating parameters such as accuracy, resolution, range, hysteresis, settling time, stability.</p>

<b>Assessment focus LO.4</b>	
Mark Band 1–3 (0–10 marks)	<p>Up to 2 marks can be awarded for the description of the PLC system and up to 2 marks for explaining advantages and disadvantages. Typically 2 marks could be awarded for an answer that included a description of some of the system components and 2 marks for an explanation of advantages and disadvantages. Where either the description of the system or the explanation of the advantages and disadvantages are beyond mark band 1 requirements this could go to 3 marks, up to a maximum of 4 marks across mark band 1.</p> <p>1 mark can be awarded for an explanation of the operation of the system. A typical answer could include an explanation of ladder logic and programming scanning for changes to inputs and outputs. Up to 2 marks can be awarded for developing the program (NB: The proficiency in programming should be taken into account in awarding the marks, with only full marks given when the activity is completed in an efficient and safe manner. It should also demonstrate an appropriate structure and should use correct logic).</p> <p>Up to 2 marks can be awarded for the evaluation of the PLC system's operation and 1 mark for the evaluation of its associated control program. Typically an answer could include an evaluation of a PLC in relation to achieving the desired functionality in terms of input sensing (1 mark) and output control (1 mark). Typically, the evaluation of the control program could make reference to either: structure and control flow, optimisation and/or minimisation.</p>

<b>Assessment focus LO.5</b>	
Mark Band 1–3 (0–17 marks)	<p>Up to 3 marks can be awarded for a correctly laid out block diagram and 4 marks for indicating the types of sensors, transducers, actuators and displays. Typically a block diagram should include inputs, outputs, and where appropriate energy sources, controller, additional signal conditioning. It should show the inclusion of sensors, transducers, actuators and displays.</p> <p>Up to 3 marks can be awarded for a description and inclusion of the signal conditioning and 3 marks for a description of the control program used. Typically a description of signal conditioning might include, up to a maximum of 3 marks and including any three of the following, awarding 1 mark for each described: (i) amplification, (ii) filtering, (iii) DC level shifting, (iv) analogue to digital conversion (ADC), (v) digital to analogue conversion (DAC), (vi) noise reduction, (vii) attenuation, (viii) code conversion. Typically a description of the control program might include, up to a maximum of 3 mark and including any three of the following, awarding 1 mark for each described: (i) program initialisation, (ii) scanning and/or polling, (iii) reading data/controls, (iv) processing, (v) updating displays, (vi) data storage.</p> <p>Up to 2 marks should be awarded for the evaluation of the application of control engineering and 2 marks for the justification of the choice of components (including sensors, transducers, actuators, signal conditioning, displays and the control program used). Typically an answer could include an evaluation of a control system in relation to achieving the desired functionality in terms of meeting the desired specification (1 mark) and the overall functionality achieved (1 mark). Typically, the justification of the choice of components could make reference to, up to a maximum of 2 marks and any two of the following, awarding 1 mark for each justification: (i) speed of operation, (ii) accuracy, (iii) stability, (iv) repeatability, (v) energy and efficiency.</p>

## Approaches to assessment

In all cases the mark band descriptions are intended to be progressive from mark band 1 to mark band 3, indicating a more complete understanding of the subject, hence the tasks should be designed with this in mind. Learners attempting mark band 3 should have the opportunity of gathering the marks for mark band 1 and mark band 2.

It is most likely that there will be a number of separate tasks that provide learners with the opportunity to achieve each of the assessment foci, an overall assignment with five tasks would be appropriate for this unit.

Task 1 could cover assessment focus 1 and could be based on an investigation of signals and transmission media used in a typical instrumentation or control system. For example, learners could investigate a system in which one or more remote analogue temperature sensors are used to collect data and then transmit this in digital form using a serial data connection to a microcontroller or monitoring computer system. This would allow learners to investigate the operation of analogue to digital converters (ADC) as well as the operation of a serial data link (eg RS-232) and the use of multiplexing and signal conditioning circuitry. As the outcomes from this task are likely to be of a written nature the evidence should be submitted in the form of a 'report'.

Task 2 could cover assessment focus 2 and involve an investigation of a variety of different types of sensor, transducer and display and their role within typical instrumentation and control systems. Typical systems could be based on position control, temperature control or speed control and could be based on analogue, digital and mixed (analogue/digital) technology. Again, as the outcomes from this task are likely to be of a written nature the evidence should be submitted in the form of a 'report'.

Task 3 could cover assessment focus 4.3 and could be based on an investigation of open and closed loop control systems including an observation and quantitative measurement of parameters such as resolution, accuracy, settling time, hysteresis, overshoot, undershoot (etc). Learners should be given the opportunity to change system parameters (such as closed-loop gain, feedback ratio, etc) and to measure and observe the results on system behaviour. Again, as the outcomes from this task are likely to be of a written nature the evidence should be submitted in the form of a 'report'.

Task 4 could cover assessment focus 4 and could be based on a PLC system with a limited number of inputs and outputs for controlling a simple industrial process (such as a simple conveyor system). The task should include activities that could be based on the use of simulation software or the use of a software program which could be downloaded to the PLC. Alternatively, a hand-held programmer could be used for program entry, debugging and modification. In all cases the task should be realistic, with input sensors and output displays or actuators and an appropriate degree of complexity. Some of the outcomes from this task are likely to be of a written nature and, together with the evidence to support the programming carried out for mark band 2, evidence should be submitted in the form of a 'process portfolio'.

Task 5 could cover assessment focus 5 and could be based on a detailed investigation of a complete application of a control engineering system. This might be based on an engine management system, automatic braking system (ABS), guidance system, armament firing system, process control system, power generation system, plant/process control system, robot manufacturing cell, robot handling system, industrial conveyor system, computer numerical control (CNC) system. Again, as the outcomes from this task are likely to be of a written nature the evidence should be submitted in the form of a 'report', this would obviously need to include the block diagrams.

## Guidance for teaching this unit

### Delivery guidance

This unit is 60 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 20 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

Where possible, this unit should be taught through a series of practical investigations based on instrumentation and control systems of different types and complexity. Whilst the learning outcomes are about knowledge and understanding, this is best developed primarily through practical work/demonstrations and industrial visits. Simulation software could be used in many situations, as could commercially available control and instrumentation systems.

Although the learning outcomes are presented in a particular order it is not necessary, or even desirable, to teach them in this order. Care should be taken to ensure that the necessary underpinning knowledge is covered before learners undertake any work that is to be assessed.

In learning outcome 1, the investigation/demonstration of signals and transmission methods should include, for example, cabling, twisted pair (both shielded and unshielded), Ethernet, CAT5, co-axial, optical fibre and radio and the reasons for their use. Opto-isolators, and the reasons for including them in the system could be introduced. Hydraulic and pneumatic systems and their use in potentially explosive atmospheres should form part of the teaching. The data communications and multiplexers should include reference to the various protocols, eg RS423, IEEE, USB, Field bus, Profibus (Process Field Bus), CAN (Controller Area Network), LIN (Local Interconnect Network), and RFID (Radio frequency identification). Learners should be introduced to the attributes of analogue and digital signals and the basic concepts of the operational amplifier before going on to study A to D and D to A converters including the Nyquist-Shannon sampling theorem.

In learning outcome 2 the investigation/demonstration of sensors might include moiré fringe, incremental and absolute encoders, proximity, micro, magnetic reed, float, switches, passive infra red. Transducers might include capacitive, inductive, resistive, piezo electric, Hall Effect, pressure, flow, magnetic reluctance, LDR and photo-detective devices, temperature, displacement, acceleration and micro chip sensors. Actuators should include pneumatic and hydraulic as well as electrical devices. Instrumentation should include analogue as well as digital displays and the relative advantages and disadvantages of each. Learners should be encouraged to use manufacturers' data sheets to obtain physical and input/output characteristics, and in a practical situation use a number of sensors and transducers in an instrumentation or control circuit.

Learning outcome 3 lends itself to some practical delivery. It should include open loop, closed loop, feed-forward, feedback, gain, hysteresis, signal processing and conditioning, damping, overshoot, settling time, hunting, stability and instability, disturbances and rejection, compensation, input, output, set point, demand value, error and steady state error. Proportional-Integral-Derivative Control should also be included. Although the mathematics should be constrained to that expected of a level 3 unit, a descriptive use of Nyquist and Bode plots to show the results of open loop testing might be used.

In learning outcome 4 learners should be introduced to the basic concept of the PLC and also to some possible alternatives, eg PICs and microcontrollers, and understand the relative advantages and disadvantages of each. They should experience programming a PLC to carry out some control functions, as used in industry. This could link to the section on sensors and actuators, with the inputs connected to sensors and the outputs driving actuators. The use of simulation software would be of advantage.

The investigation of a real control system for assessment focus 5 should bring together most of the elements of this unit. Examples might include engine management systems, automatic braking systems (ABS), guidance systems, armament firing systems, process control systems, power generation systems, plant/process control systems, robot manufacturing cells, robot handling systems, industrial conveyor systems, computer numerical control (CNC) systems. Regardless of the system(s) chosen for investigation, an emphasis should be placed on the use of current and future technology. To satisfy this requirement, learners should be encouraged to explore the future possibilities and applications of automation and control technology and tutors should ensure that learners are provided with appropriate guidance and access to relevant information sources.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	<p>Identifying coursework questions and problems to resolve.</p> <p>Describing the fundamental characteristics of analogue and digital signals and explaining the need for different types of transmission media. Assessment focus 1.</p> <p>Describing simple instrumentation and control systems and explaining the role of digital and analogue sensors, transducers and displays in instrumentation and control applications. Assessment focus 2.</p> <p>Describing an industrial or domestic application of control engineering and drawing a block diagram of the system, indicating the types of sensors, transducers, actuators and displays. Assessment focus 5.</p>
<b>Creative thinkers</b>	<p>Trying out alternatives or new solutions and following ideas through, adapt ideas as circumstances change.</p> <p>Describing a simple PLC system and explaining its advantages and disadvantages. Assessment focus 4.</p>
<b>Reflective learners</b>	<p>Setting goals for the development of each of their assignments.</p> <p>Reviewing their progress against the completion of their assignments.</p> <p>Describing an industrial or domestic application of control engineering and drawing a block diagram of the system, indicating the types of sensors, transducers, actuators and displays. Assessment focus 5.</p>
<b>Team workers</b>	Not present in this unit.
<b>Self-managers</b>	<p>Work towards goals, showing initiative, commitment and perseverance organise time and resources, prioritising actions.</p> <p>Describing an industrial or domestic application of control engineering and drawing a block diagram of the system, indicating the types of sensors, transducers, actuators and displays. Assessment focus 5.</p>
<b>Effective participators</b>	Not present in this unit.

## Functional skills – Level 2

This unit provides opportunities for the development of functional skills in English, particularly when learners are using texts and other sources of information to research industrial application of instruments. The unit also has opportunities for the development of functional skills in mathematics, particularly when learners use appropriate mathematical procedures to calculate dimensions, scales and drawing ratios.

Learners can also develop functional skills in ICT when they are learning about storage and security of ICT systems and how to select and use appropriate software applications and consider the engineering applications of the software.

### Work experience

This unit would benefit from work experience in a number of industries which use instrumentation and control. If work experience were not possible in these industries it would be beneficial to include industrial visits.

### Specialist resources

Centres will need to provide learners with access to the following resources:

- control simulation software
- electronics simulation software
- PLCs and programming software
- examples of open loop, closed loop and PID control systems
- various sensors, transducers and actuators
- analogue and digital instruments and displays
- examples of industrial and domestic control systems.

### Reference material

Bolton W – *Instrumentation and Control Systems* (Newnes, 2004) ISBN 0750664320

Bolton W – *Programmable Logic Controllers* (Elsevier, 2006) ISBN 9780750681124

Parr E – *Programmable Controllers – an Engineer's Guide* (Newnes, 2003)  
ISBN 9780750657570

Sinclair I – *Sensors and Transducers* (Newnes, 2000) ISBN 9780750649322

Tooley M – *PC Based Instrumentation and Control* (Elsevier, 2005) ISBN 9780750620932



# Unit 5: Maintaining Engineering Plant, Equipment and Systems

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**Principal Learning unit**

**Level 3**

**Guided Learning Hours: 30**

**Internally assessed**

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## **About this unit**

Maintenance engineers are responsible for ensuring that engineering plant, equipment or systems are properly maintained and kept in service. This can contribute towards the competitiveness of the company or organisation concerned. As such, maintenance engineers are often seen as key employees and can typically earn in excess of £25,000.

In this unit you will get involved with both planning and carrying out maintenance activities. You will discover what may happen when things go wrong and are not properly maintained. You will find out about the consequences of plant, equipment or systems failure and what happens to production when these are not properly maintained. You will also find out about how data is collected and used to check on performance and the condition of the plant, equipment or system. You will look at maintenance strategies and with this knowledge plan a maintenance activity. You will also carry out a risk assessment that is required before you carry out a maintenance activity when following a maintenance plan.

This is a practical unit that will involve hands-on activities, putting knowledge and understanding into practice. The unit lends itself to support from local workplace providers so you may well receive an insight into maintenance activities within a real engineering environment.

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## Learning outcomes

On completion of this unit, a learner should:

- LO.1. Know about the cost of maintenance and the consequences of plant, equipment or system failure including the effects on production
  - LO.2. Be able to deploy effective maintenance strategies when planning a maintenance activity
  - LO.3. Know how the data gathered from monitoring the performance and condition of engineering plant, equipment or system can be used
  - LO.4. Be able to carry out a risk assessment and follow a maintenance plan using documentation for a maintenance activity on a closed loop engineering system.
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## What you need to cover

- LO.1 Know about the cost of maintenance and the consequences of plant, equipment or system failure including the effects on production**
- Learners will need to investigate effects on corporate image and customer expectation, eg cost, penalties, contractual breach, health and safety, regulatory breach (including breach of European standards); and the consequences of failure, eg health and safety, environmental effects, quality, equipment life, maloperation.
- Learners will research the effects on production, eg downtime, production stoppages, effects on operating performance, product quality, effects on associated equipment or plant, higher energy costs, secondary damage.
- Learners will also examine the costs of poor maintenance by looking at the way the records of costs are represented, eg maintenance as a proportion of total expenditure, utilisation of operator (front-line maintenance), maintenance labour, maintenance contracting, lost production, levels of spares and consumables in stores, equipment hire/replacement, safety and environmental effects.
- LO.2 Be able to deploy effective maintenance strategies when planning a maintenance activity**
- Learners will need to investigate effective types of maintenance strategies, eg planned, total preventative maintenance (TPM), breakdown, scheduled, corrective, reactive, predictive, run to failure, emergency, post fault, scheduled servicing, modification to equipment, condition-based maintenance.
- Learners will apply these to develop a maintenance plan that will involve a range of features breaking these down to manageable steps, eg safe working procedures, permit to work, spares lists, skills levels, sub contract, equipment, tools, manuals, materials, components, sequence and timing, frequency, check lists. They will then present their plan using appropriate methods, eg Gantt charts, maintenance logs, job cards, databases, records, reports, production records, standing instructions, hand-over procedures, computerised methods.
- LO.3 Know how the data gathered from monitoring the performance and condition of engineering plant, equipment or system can be used**
- Learners will need to consider monitoring techniques such as condition monitoring, scheduled overhauls, routine servicing, planning systems, hazard studies, failure mode and effect analysis (FMEA), self-diagnostic and computerised systems.
- Learners will need to examine how data is collected from identified points. In doing so they will find out about data, eg types, operational characteristics, output quality, throughput, environmental operating conditions; and how to interpret data, eg electronic-based data, data recording and presentation.
- Learners will also discover the need for monitoring considering physical aspects, eg improve safety, reduce environmental hazards, extended equipment life; and cost related aspects, eg improve product quality, reduce downtime, reduce costs; and other aspects, eg comprehensive computer database, better communications.

**LO.4. Be able to carry out a risk assessment and follow a maintenance plan using documentation for a maintenance activity on a closed loop engineering system**

Learners will need to follow a maintenance plan that will include a risk assessment (such as the five steps including principal hazards, who is likely to be injured/harmed, evaluate the risks and decide on adequacy of precautions, recording findings, review assessment) and other relevant safety conditions, eg COSHH, safe access and working arrangements for the maintenance area, isolation requirements for plant/equipment, disposal of waste, hand-over procedures, liaison with other departments.

The supporting documentation that learners use will include as appropriate, manufacturers' drawings and maintenance documentation, eg maintenance logs, data bases, records, results and defect reports, plans and schedules, production records, standing instructions, hand over documentation.

Learners will carry out the maintenance activity on a closed loop engineering system such as process monitoring and control, eg mechanical, fluid power, electrical, process control, automotive system, chemical production system, environmental systems (fume extraction or air conditioning), machine tool, lifting and handling equipment, process control valves, company specific equipment, electrical plant, motors starters, switchgear and distribution panels. The maintenance activities should be appropriate to the closed loop system being maintained, eg visual examination, monitoring, replacement, sensory, testing, checking alignment, making routine adjustment, removing excess dirt and grime, recording results and reporting defects.

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## How you will be assessed

This unit focuses on developing the knowledge and skills required by a maintenance engineer, and as such you will be assessed through an assignment giving opportunities, through a theme of maintenance, to demonstrate that you know about the consequences of failure of plant, equipment or systems and how the costs to maintain these are represented. You will be expected to show that you can develop and follow a maintenance plan safely and carry out a risk assessment. You will also need to demonstrate what you know about monitoring techniques and the way data is collected and used. These are similar topics to those that a maintenance engineer working in industry is likely to come across.

This unit will be assessed by your tutor who will set an assignment for you to complete. You are likely to be given one or more tasks which will cover all the material you have studied. At least some of these tasks will be set in the workshop and may relate to your work experience. Your tutor will give you opportunities to develop evidence. These opportunities could typically consist of three tasks.

Task 1 could cover the requirements for assessment foci 1.1, 1.2 and 2.1 and could include activities for you to follow. You would therefore be asked to give a written response to these activities and the evidence should be presented in a 'report'.

A second task could bring together assessment foci 2.2 and 4 and would be of a practical nature. As such the evidence for task 2 should be in the form of a 'process portfolio'. This second task as a mainly practical assignment will be the main assessment in this unit and thus carries a higher weighting of marks. It will therefore give you an opportunity to develop and use your practical skills applied to maintenance planning and maintenance tasks.

The third and final task could be a mixture of written activities at the end for you to do and a practical activity which could cover the requirements of the assessment focus 3. As such evidence for task 3 should be in the form of a 'process portfolio'.

In all of your tasks it is best that you work, as best you can, on your own to carry out the activities. However you must not do anything that may cause a problem or be dangerous when using equipment, particularly when carrying out the maintenance activity on a closed loop system.

## Marking grid A

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.1.1</b> <b>Know about the consequences of plant, equipment or system failure and the effects on production</b>	Describes the consequences of failure for given plant, equipment or a system and describes the effects on production.  (0–4)	Describes the consequences of failure for given plant, equipment or a system, describes the effects on production and explains the effect on customer expectation and corporate image.  (5–7)	Describes the consequences of failure for given plant, equipment or a system, describes the effects on production, explains the effect on customer expectation and corporate image and compares two consequences of plant, equipment or system failure for their effect on corporate image.  (8–9)	9
<b>LO.1.2</b> <b>Know about the cost of maintenance</b>	Describes how the costs of maintenance are represented for given plant, equipment or a system.  (0–3)	Describes how the costs of maintenance are represented for given plant, equipment or a system and describes the benefits of keeping accurate cost records of maintenance.  (4–5)	Describes how the costs of maintenance are represented for given plant, equipment or a system and describes the benefits of keeping accurate cost records of maintenance including a justification for the use of the records in a maintenance environment.  (6–7)	7
<b>LO.2.1</b> <b>Effective maintenance strategies</b>	Describes two given types of maintenance strategies.  (0–4)	Describes two given types of maintenance strategies and describes how one would be used for given plant, equipment or a system.  (5–6)	Describes two given types of maintenance strategies and describes how one would be used then justifies why it would be used for given plant, equipment or a system.  (7–8)	8

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.2.2</b> <b>Plan a maintenance activity</b>	Develops a maintenance plan and uses two appropriate methods to present the plan for a given type of maintenance strategy.  (0–4)	Develops a maintenance plan and uses two appropriate methods to present the plan for a given type of maintenance strategy and explains how the methods used to present a maintenance plan help deploy a maintenance strategy.  (5–6)	Develops a maintenance plan and uses two appropriate methods to present the plan for a given type of maintenance strategy, explains how the methods used to present a maintenance plan help deploy a maintenance strategy, justifies a maintenance plan and considers an alternative approach to improve the deployment of a maintenance strategy.  (7–8)	8
<b>LO.3</b> <b>Know how the data gathered from monitoring the performance and condition of engineering plant, equipment or system can be used</b>	For a given monitoring technique describes how data would be collected and interpreted when considering physical, cost related, and other aspects.  (0–6)	Describes how data would be collected and interpreted and uses data from a given monitoring technique to review physical, cost related, and other aspects that show the performance and condition of engineering plant, equipment or a system.  (7–10)	Describes how data would be collected and interpreted and uses data from a given monitoring technique to review and then justify the use of this data to help improve the performance and condition of engineering plant, equipment or a system.  (11–14)	14

## Marking grid B

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<p><b>LO.4</b>  <b>Be able to carry out a risk assessment and follow a maintenance plan using documentation for a maintenance activity on a closed loop engineering system</b></p>	<p>Completes a risk assessment, then follows a given maintenance plan and uses supporting documentation to carry out, with guidance, appropriate maintenance activities on a closed loop engineering system.</p> <p>(0–6)</p>	<p>Completes a risk assessment, then follows a given maintenance plan deploying other relevant safety conditions and uses supporting documentation to carry out, with limited guidance, appropriate maintenance activities on a closed loop engineering system.</p> <p>(7–10)</p>	<p>Completes and evaluates a risk assessment, then follows a given maintenance plan deploying other relevant safety conditions and effectively uses supporting documentation to carry out, independently, appropriate maintenance activities on a closed loop engineering system.</p> <p>(11–14)</p>	<p>14</p>
<b>Total marks</b>				<p>(9+7+8+8+14+14) = 60</p>

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to award marks within each mark band in an objective way.

### Marking grid A

<b>Assessment focus LO.1.1</b>	
Mark Band 1–3 (0–9 marks)	<p>There are typically up to 2 marks for each of the two descriptions, but could go to 3 marks if either the consequences of failure or the effect on production is answered well and above that required for this mark band but up to a maximum of 4 marks.</p> <p>Up to 2 marks can be awarded for the explanation of the effects and should be based on the how well it shows the effects are appropriate to customer expectation and corporate image and 1 mark can be awarded for linking image and customer expectation within the explanation.</p> <p>Up to 2 marks could be awarded for indicate why consequences affect corporate image; this could be in the form of advantages and limitations.</p>

<b>Assessment focus LO.1.2</b>	
Mark Band 1–3 (0–7 marks)	<p>Up to 3 marks can be awarded for describing how the costs are represented based on its ability to show the link between cost and maintenance.</p> <p>Up to 2 marks can be awarded for the description based on the appropriateness of the benefits of keeping records.</p> <p>The justification should indicate why records are appropriate; this could be in the form of advantages and limitations. Up to 2 marks can be awarded for the justification given based on its clarity and ability to show advantages and/or limitations.</p>

<b>Assessment focus LO.2.1</b>	
Mark Band 1–3 (0–8 marks)	<p>There are typically up to 2 marks for each of the two descriptions, but could go to 3 if one aspect is answered well and above that required for this mark, up to a maximum of 4 marks. The marks given should be based on the detail given to show what each type of maintenance strategy is.</p> <p>Up to 2 marks can be awarded for the description of how a maintenance strategy would be used based on the detail given.</p> <p>Up to 2 marks can be awarded for the justification given based on its clarity and ability to show advantages and/or limitations.</p>

<b>Assessment focus LO.2.2</b>	
Mark Band 1–3 (0–8 marks)	<p>A maintenance plan is likely to have the following aspects present: safe working procedures, permit to work, spares lists, skills levels, sub contract, equipment, tools, manuals, materials, components, sequence and timing, frequency, check lists. A maintenance plan should have a range of these present for the given activity. 1 mark can be awarded for every two of these aspects present, based on their suitability and detail against the given activity, up to a total of 2 marks. If more are present the maximum mark for the plan is still 2. The plan also has to be presented, this can be achieved by any of the following methods: Gantt charts, maintenance logs, job cards, data bases, records, reports, production records, standing instructions, handover procedures, computerised methods. 1 mark can be awarded for every two of these methods used, based on their suitability and detail against the given activity, up to a total of 2 marks.</p> <p>Up to 2 marks can be awarded for the explanation given based on the detail included to show how methods of presentation can influence the successful deployment of a maintenance strategy and about the visibility of the information shown.</p> <p>1 mark can be awarded for justifying its use to include how the maintenance plan is able to be followed and gives limitations and benefits in its use. One mark can be awarded for giving ideas about how it could be improved when used for a particular maintenance strategy.</p>

<b>Assessment focus LO.3</b>	
Mark Band 1–3 (0–14 marks)	<p>Typically, up to 3 marks can be awarded for each description of both collection and interpretation of data based on the consideration of physical aspects, cost related aspects and other aspects in each case. If either area of collection or interpretation is answered well and beyond that required for mark band 1, 4 marks could be awarded up to a maximum of 6 marks.</p> <p>Marks can be awarded when the learner uses data from the monitoring technique to review (i) the performance of the engineering plant, equipment or system and (ii) the condition of the engineering plant, equipment or system. There are typically up to 2 marks for each of the two aspects of the response but could go to 3 if one aspect is answered well and above that required for mark band 2 but up to a maximum of 4 marks.</p> <p>Marks can be awarded when the learner justifies the use of data used to help monitoring techniques to help improve (i) the performance and (ii) the condition of the engineering plant, this could be in the form of advantages and limitations. There are typically up to 2 marks for each of the two aspects of the response.</p>

**Marking grid B**

<b>Assessment focus LO.4</b>	
<p>Mark Band 1–3 (0–14 marks)</p>	<p>If the risk assessment produced is of a basic nature, up to 2 marks can be awarded. A basic risk assessment is likely to have four of the five steps completed in a simplistic way. A more comprehensive risk assessment can be awarded up to 3 marks and will have all five steps completed. Up to 2 marks can be awarded for the evaluation of the risk assessment. One mark can be awarded for using relevant supporting documentation, apart from the maintenance plan and another mark should be awarded when it is effectively used, which will mean the links made and usefulness, when using this documentation, are very clear. Up to 2 marks can be awarded for relevant safety conditions followed.</p> <p>Up to 3 marks can be awarded for the maintenance activity carried out with guidance and based on how well it follows the plan and supporting documentation. In all cases the learner has to be guided and advised throughout to ensure that progress is made. The learner relies on the support of the tutor, who has to assist in most aspects of the work.</p> <p>Up to 4 marks can be awarded for the maintenance activity carried out with limited guidance and based on how well it follows the plan and supporting documentation. The tutor supports the learner initially in carrying out the risk assessment, following relevant safety conditions and carrying out the maintenance activity. Thereafter the tutor reacts to questions from the learner and suggests a range of ideas/activities that the learner acts on. The learner frequently checks matters of detail. The tutor needs to assist in some aspects of the work.</p> <p>Up to 5 marks can be awarded for the maintenance activity carried out independently and based on how well it follows the plan and supporting documentation. The tutor supports the learner initially in carrying out the risk assessment, following relevant safety conditions and carrying out the maintenance activity. Thereafter the tutor occasionally assists the learner, and only when asked, but monitors progress throughout.</p>

## Approaches to assessment

Progression across the mark bands will be achieved when learners cover the requirements of each assessment focus in more detail. Assessment foci 1.1, 1.2, 2.1, 3 and 4 provide opportunities for learners to progress across the mark bands by applying their knowledge and skills in a more analytical manner.

Learners will need to meet the requirements of each mark band as they progress through the set tasks. Assessment focus 2.2 will need individual activities for each level of performance, indicated by each part within each mark band.

In order to reflect the applied nature of the qualification, a greater weighting of marks in this unit has been allocated to assessment foci 3 and 4. These provide opportunities for learners to apply their knowledge and understanding to practical, problem solving activities, with guidance, with limited guidance or independently.

Assessment evidence for this unit could typically consist of an assignment containing three tasks, although these do not have to be taken separately. This unit should be assessed by short tasks taken under supervised conditions, in suitable teaching sessions.

Task 1 will require evidence in the form of a 'report'. It could cover the requirements of assessment foci 1.1, 1.2 and 2.1. It may be appropriate to administer this task over two or three hours. The centre has freedom of choice with regards to plant, equipment or system used for the task, although it would depend on the experience that learners have had during the delivery of this unit (see delivery guidance).

For assessment focus 1.1 written activities will need to be set asking for descriptions of consequences of failure, effects on production, an explanation of how the effects on production effect customer expectations and corporate image, and a comparison of the consequences of plant, equipment or system failure for their affect on corporate image.

Further written activities for assessment focus 1.2, to describe how the costs are represented and the benefits of keeping accurate cost records and to justify the use of those records could be given.

Finally, to give opportunities to achieve assessment focus 2.1 a further set of written activities should be given that ask the learner to describe two given types of maintenance strategies, different learners could be given different strategies from those listed in the 'what you need to cover' section, and describe how one would be used for a particular plant, equipment or system and justify it's use. If it was necessary for a learner to retake this task, different plant, equipment or system should be given for assessment focus 1.1 and 1.2 and different types of maintenance strategies for assessment focus 2.1.

Task 2 will require evidence in the form of a 'process portfolio'. This second task could cover assessment foci 2.2 and 4 as a practical task and as such may have to be controlled over more than one teaching session. It may be appropriate to administer this task over five or six hours. Learners will need to be given a maintenance activity to plan and carry out. The task should ensure through the planning of the activity that at least four of the range of features found in a maintenance plan will be needed and at least two methods of presentation of maintenance plans will be needed.

Once the plan is completed learners need to be prepare a risk assessment for the activity and use supporting documentation other than the plan itself and the risk assessment. The activity(s) may have to be explicit about this otherwise the full range of marks may not be possible.

Assessment foci 2.2 and 4 will require practical work and as such may need a learner observation record sheet supplemented by annotated photographs and diagrams as well as annotation on the given maintenance activity and other documentation. This evidence should clearly state the level of support given to the learner and be detailed enough for the assessor to judge whether the response falls into mark band 1, 2 or 3. The risk assessment for assessment focus 4 will obviously be supporting ‘product type’ evidence.

Further written activities will be required whereby the learner is asked to explain the methods used to present their maintenance plan, justify the plan and consider an alternative for assessment focus 2.2. Another written activity following the practical work should ask the learner to evaluate the risk assessment for assessment focus 4.

If it is necessary for a learner to retake this task, a different type of maintenance strategy for assessment focus 2.2 and a different maintenance plan for assessment focus 4 is required. There is also an opportunity to supply different supporting documentation for assessment focus 4.

Task 3 could cover assessment focus 3 and will require evidence in the form of a ‘process portfolio’. The task will require a mixture of practical and written activities and as such it may be appropriate to administer this task over two or three hours.

Learners should be given an activity to describe how data would be collected and interpreted. They must be given an opportunity to consider the range of physical, cost and other related aspects as required by mark band 1. They should then be asked to use some data to review a monitoring technique for these aspects to show both performance and condition of either plant, equipment or a system. A final activity needs learners to reflect on the use of this data and justify the use of the data to help make improvements to the performance and condition of engineering plant, equipment or a system. If it was necessary for a learner to retake this task, a different monitoring technique should be given for assessment focus 3.

The approach outlined above would allow these tasks to be carried out on a work experience placement provided the right organisation could be found. In this case the centre staff will need to brief the company staff and engineers very carefully about the unit requirements. It is important to remember that often an employer will want a different form of evidence. This may be in the form of a ‘paper’ or a ‘briefing note’ or a formally structured ‘report’. In supporting an employer the diverse range of forms of evidence should be taken into consideration. In these cases learner observation record sheets, annotated photographs and video recordings of what the learner did will be vital. In task 2, the maintenance activity could be real and supplied by the company.

## Guidance for teaching this unit

### Delivery guidance

This unit is 30 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 10 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

Although the learning outcomes are in a logical order for assessment purposes, the last learning outcome, which requires learners to follow a maintenance plan for a given activity, will need to be taught in such a way that it compliments the rest of the content delivery. As such, the way to carry out a risk assessment should be taught as soon as sufficient experience of maintenance terminology has been gained. This will also allow a better understanding of the requirements of a maintenance plan in outcome 2. Apart from this consideration the learning outcomes could be taught in the order they appear in the content.

It is important that learners investigate a range of consequences and what can go wrong in maintenance. This should extend learners' understanding of the effects of poor maintenance at a more strategic/management level. This should cover the effects on production but should differentiate between what happens to production and what could happen beyond, effects on customer expectations and damage to corporate image.

The plant, equipment or system given for study/assessment should be sufficiently important to the engineering organisation that consequences would be felt from the customer base should this plant, equipment or system go wrong. A single machine, in many instances, such as found in a batch production environment, may not have this effect. A 'bottleneck' resource such as a packaging machine at the end of an automatic production line may well have this strategic importance and would be suitable.

Visits to or placements in organisations that have a maintenance department or function would be helpful in giving learners first-hand experience of maintenance activities. Some organisations may have first-hand experience or case studies of consequences and effects on production. Alternatively, a visit to the centre by a maintenance engineer to talk about these issues would also be beneficial. Learners will also need to be taught about how this all interacts with costs and how these costs are aligned and measured/reported on.

Learners will need to find out about the different types of maintenance strategies and investigate where and how these are applied to develop a maintenance plan. The relevance of each of the features found within a typical maintenance plan should be discussed and learners will need to practice methods of presenting a plan and discuss the application and relevance of each of the methods suggested in the 'what you need to cover' section.

For learning outcome 3 learners will need to examine how data is collected and used when it comes to monitoring both condition and performance of plant, equipment or a system. Again any organisation with a maintenance department may have set procedures for collecting data from a variety of sources and be able to show how it is used to improve physical and cost related aspects.

Opportunities should be taken throughout the delivery of this unit to highlight the health and safety requirements of the last learning outcome. It is important that learners are made aware of the correct use of risk assessments and other safety issues relevant to maintenance activities. It is important to cover the safety issues that are likely to be required for any maintenance activity that will be carried out during the delivery and assessment of this unit.

The use of industrial visits or a visiting engineer would develop learners' knowledge of the consequences of failure, the affects of poor maintenance, collection and use of data and health and safety requirements. Whilst some of the learning outcomes require knowledge of maintenance, the approach of utilising industry and their current practices will give a very practical nature to the delivery throughout the unit.

The use of the internet to research the health and safety requirements and risk assessments is something that learners might find rewarding. In a classroom situation, motivational practices such as setting up a competition on who can identify the most health and safety requirements that a maintenance engineer is likely to come into contact with, might also enliven delivery.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	Identifying coursework questions and problems to resolve. Describing the consequences of failure for given plant, equipment or a system and describing the effects on production. Assessment focus 1.1.
<b>Creative thinkers</b>	Not present in this unit.
<b>Reflective learners</b>	Setting goals for the development of each of their assignments. Reviewing their progress against the completion of their assignments. Developing a maintenance plan and using two appropriate methods to present the plan for a given type of maintenance strategy. Assessment focus 2.2.
<b>Team workers</b>	Not present in this unit.
<b>Self-managers</b>	Planning and organising the creation of their assignments for this unit. Dealing with time pressures and deadlines for the production of their assignments. Seeking advice and support from their peers and tutors when needed. Developing a maintenance plan and using two appropriate methods to present the plan for a given type of maintenance strategy. Assessment focus 2.2. Completing a risk assessment, then following a maintenance plan and using supporting documentation to carry out appropriate maintenance activities on a closed loop engineering system. Assessment focus 4.
<b>Effective participators</b>	Developing a maintenance plan and using two appropriate methods to present the plan for a given type of maintenance strategy. Assessment focus 2.2. Completing a risk assessment, then following a maintenance plan deploying other relevant safety conditions and uses supporting documentation to carry out, with guidance, appropriate maintenance activities on a closed loop engineering system. Assessment focus 4.

## Functional skills – Level 2

This unit provides opportunities for the development of some of the functional skills in English, particularly when learners are describing consequences of failure, how costs are represented and types of maintenance strategies.

The unit also provides opportunities for the development of functional skills in mathematics, particularly when learners are using data to review a monitoring technique and interpreting and communicating the results and solutions and drawing conclusions to show the performance and condition of plant, equipment or a system.

### Work experience

This unit can be delivered and evidence gathered from a work placement. Learning about maintenance strategies, activities and things that can go wrong (consequences and effects on customer interfaces and production) when applied to a real engineering company will maximise learners' understanding.

Engineering companies are likely to have maintenance activities that learners could follow and maintenance requirements that will need data to be collected and interpreted and a range of maintenance tasks that would require a risk assessment to be carried out. Centres who can utilise work experience will maximise their learners' opportunities to succeed.

### Specialist resources

Much of the content for this unit can be structured into case study material that takes into account industrial practice and materials and centres should allow time for the development of these materials.

Centres will also need to identify a range of locally available engineered plant, equipment and systems on which learners can base their maintenance investigations. In addition, specialised reference material, such as health and safety regulations and examples of a range of documentation as listed within the 'what you need to learn' section should be made available to learners. A well stocked library, complete with internet research facilities, should also be provided. Appropriate health and safety materials, including a range of signs and warning notices, should be prominently displayed in workshops and practical resource areas.

Centres should also consider the use of resources that can be accessed within local industry. These are likely to make excellent resources for the generation of case study materials and will usefully help to bring to life the more theoretical parts of this unit. Industrial contacts will usually be able to suggest maintenance tasks that learners can observe, including those that involve testing, inspection and the replacement of worn components and consumable materials.

### Reference material

Hawkins B and Smith R – *Lean Maintenance: Reduce Costs, Improve Quality and Increase Market Share* (Butterworth-Heinemann, 2004) ISBN 0750677791

Hughes P and Ferrett E – *Introduction to Health and Safety at Work* (Elsevier, 2005) ISBN 0750666234

Levitt J – *Complete Guide to Predictive and Preventive Maintenance* (Industrial Press, 2002) ISBN 0831131543

Palmer R – *Maintenance Planning and Scheduling Handbook* (McGraw-Hill, 2006) ISBN 0071457666

## Unit 6: Investigating Modern Manufacturing Techniques used in Engineering

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Principal Learning unit

Level 3

Guided Learning Hours: 60

Internally assessed

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### About this unit

British engineering industries have been revolutionised in the last 10 years by new technologies and new ways of working. In this unit you are going to engage with engineering manufacturing industry and discover for yourself the transformation that has taken place.

You will learn about new and innovative production systems and the processes that are now employed in this vibrant sector of the British economy. You will be able to examine where new ‘lean manufacturing’ systems are used and where different levels of automation can be effectively deployed.

The unit will also provide you with the opportunity to put your knowledge of production planning, quality control and associated techniques into practice through practical activities done in collaboration, where possible with industry. You will also have an opportunity to work in a team when collecting and sharing data for generating charts for use in quality control and assurance.

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### Learning outcomes

On completion of this unit, a learner should:

- LO.1. Understand the differences between traditional and modern manufacturing production systems used within engineering industries
  - LO.2. Understand how different types of manufacturing processes utilise computer aided manufacturing systems
  - LO.3. Be able to plan for the production of an engineered product for industry
  - LO.4. Be able to work in a team and apply quality control and quality assurance systems.
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## What you need to cover

- LO.1 Understand the differences between traditional and modern manufacturing production systems used within engineering industries**
- Learners will need to find out about different traditional and modern manufacturing/production systems including assembly systems and techniques, eg jobbing shop, batch and mass production and the relative volumes associated with these systems. They will need to learn about layouts commonly used with these different systems, eg functional, cellular, and line layouts and how materials and products flow into and through these types of layout.
- Learners will investigate lean manufacturing systems, eg Just In Time (JIT) and Flexible Manufacturing Systems (FMS). They will need to know about Kanban systems, levelled production, standard operations and flow manufacturing.
- Learners will need to understand the four key points relating to manufacturing systems:
- the number of products produced
  - the production volume for each product
  - the layout and arrangements of processes and equipment to manufacture the products
  - the flow of materials through the equipment and processes.
- LO.2 Understand how different types of manufacturing processes utilise computer aided manufacturing systems**
- Learners will need to know about the different types of manufacturing processes including computer aided engineering and computer aided manufacturing used in modern engineering manufacturing industries, eg energy, chemical, polymer, electronic, aerospace, automotive.
- Learners will also examine the difference between the level of automation, eg manual, semi-automated and automated manufacturing processes, the extent to which these are employed in different industries and the reasons for this eg, productivity, quality, environmental requirements.
- LO.3 Be able to plan for the production of an engineered product for industry**
- Learners will need to know how engineering industry plans for production, eg project network analysis/critical path analysis, organising time, resources and prioritising actions, production and resource planning, production scheduling.
- Learners will need to be able to produce a plan and schedule for the production of a quantity of the same engineered product for industry using appropriate techniques. The plan will have various features, eg the sequence of operations, materials, process methods, tools, equipment and machinery to be used, critical production and quality control points, inspection and quality checks, health and safety requirements.

**LO.4 Be able to work in a team and apply quality control and quality assurance systems**

Learners will need to understand that manufactured products are required to conform to a customer's specification. This can be a combination of national or international standards and/or the customer's own standards. They will learn that the control of these standards during the production process is essential.

Learners will discover how industry employs statistical process control (SPC) to achieve quality in processes, eg using statistical tools such as mean and variance to detect whether a process is under control, limits (such as inner, outer, warning, action). Learners will study a process where variation is a problem and produce control charts in order to determine when corrective actions are required.

Learners will be introduced to and become familiar with ISO 9001, its purpose and content to help understand the process control procedure. They will also be able to work in a team to gather and share data to support quality control and assurance procedures and measures.

## How you will be assessed

This unit focuses on manufacturing engineering in relationship to planning and producing products. As such, you will be assessed through an assignment giving opportunities, through a theme of manufacturing technology to demonstrate what you know about the differences between traditional and more modern manufacturing techniques and how they utilise computer aided manufacturing, production planning and quality control and assurance systems.

This unit will be assessed by your tutor who will set tasks for you to complete. You are likely to be given one or more tasks which will cover the material you have studied. At least some of these tasks will be set in the workshop and may relate to your work experience. Your tutor will give you opportunities to develop evidence. These opportunities could typically consist of four tasks.

For example your tutor may set a separate task for each assessment foci 1 and 2, both of which require you to look at real industrial practice. Your evidence could be in the form of a 'report' or 'presentation'.

Similarly two other separate tasks could be used to enable you to complete the requirements of assessment foci 3 and 4 respectively. In this case your evidence for 3 could be a 'report' or 'presentation' and evidence for 4 will need to be submitted in a 'process portfolio'.

### Marking grid A

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<p><b>LO.1</b>  <b>Understand the differences between traditional and modern manufacturing production systems used within engineering industries</b></p>	<p>Explores the issues and explains the differences between traditional and modern manufacturing production systems in terms of number and volume of products manufactured, gives examples of typical products for each system.</p> <p>(0–6)</p>	<p>Explains the differences between traditional and modern manufacturing production systems in terms of number and volume of products manufactured, gives examples of typical products for each system and compares the layout and arrangements of the processes and equipment for a traditional and a modern manufacturing production systems and discusses how they affect the flow of materials and products.</p> <p>(7–10)</p>	<p>Explains the differences between the traditional and modern manufacturing production systems in terms of number and volume of products manufactured, gives examples of typical products for each system and compares the layout and arrangements of the processes and equipment for a traditional and a modern manufacturing production systems and discusses how they affect the flow of materials and products and analyses how a lean manufacturing system overcomes limitations in a traditional manufacturing production system.</p> <p>(11–13)</p>	<p>13</p>

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.2</b> <b>Understand how different types of manufacturing processes utilise computer aided manufacturing systems</b>	Explains the processes and level of computer aided manufacturing used to manufacture selected products in two different engineering manufacturing industries.  (0–6)	Explains the processes and level of computer aided manufacturing used to manufacture selected products in two different engineering manufacturing industries and analyses and compares the processes and level of automation used to manufacture selected products.  (7–10)	Explains the processes and level of computer aided manufacturing used to manufacture selected products in two different engineering manufacturing industries, analyses and compares the processes and level of automation used to manufacture selected products and presents a justification for the selection of processes and level of automation used.  (11–13)	13
<b>LO.3</b> <b>Be able to plan for the production of an engineered product for industry</b>	Produces a project network analysis to show the critical path for the production of a quantity of the same engineered product.  (0–7)	Produces a project network analysis to show the critical path for the production of a quantity of the same engineered product and develops a detailed production plan and realistic schedule.  (8–13)	Produces a project network analysis to show the critical path for the production of a quantity of the same engineered product, develops a detailed production plan and realistic schedule, reviews and justifies the production plan and schedule suggesting ways in which it could be improved.  (14–17)	17

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<p><b>LO.4</b>  <b>Be able to work in a team and apply quality control and quality assurance systems</b></p>	<p>Produces appropriate charts to control the output against a required standard.</p> <p>(0–4)</p>	<p>Produces appropriate charts to control the output against a required standard and analyses in detail the process control data to explain how variations affect the process and product.</p> <p>(5–7)</p>	<p>Produces appropriate charts to control the output against a required standard, analyses in detail the process control data to explain how variations effect the process and product and uses relevant parts of the ISO 9001 standards to help propose and evaluate an appropriate course of action to alleviate unwanted process variations.</p> <p>(8–10)</p>	<p>10</p>

## Marking grid B

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
LO.4 <b>Be able to work in a team and apply quality control and quality assurance systems</b>	Works in a team to collect sufficient and appropriate data from an engineering manufacturing process.  (0–3)	Works effectively in a team to collect sufficient and appropriate data from an engineering manufacturing process.  (4–5)	Plays a key role as a member of a team to collect sufficient and appropriate data from an engineering manufacturing process.  (6–7)	7
<b>Total marks</b>				<b>(13+13+17+10+7) = 60</b>

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to confirm marks within the objective approach. The guidance can be used to allocate specific marks for that band.

### Marking grid A

Assessment focus LO.1	
Mark Band 1–3 (0–13 marks)	<p>Up to 2 marks can be awarded for a satisfactory explanation of traditional and modern manufacturing systems in terms of number and volume of products produced. A further 2 marks may be awarded based on the ability to explain the differences between traditional and modern systems and another 2 marks awarded for appropriate examples of products for each system.</p> <p>Up to 2 marks may be awarded for the comparison of the layout and arrangements of processes and equipment between traditional and modern manufacturing systems, based on clear references being made to these features. A further 2 marks can be awarded if the learner states how the different layouts affect the flow of materials and products.</p> <p>Up to 3 marks may be awarded for an analysis of how a lean manufacturing system overcomes the limitations of in a traditional manufacturing production system.</p>

Assessment focus LO.2	
Mark Band 1–3 (0–13 marks)	<p>The learner will explain the processes and level of computer aided manufacturing used to manufacture selected products, up to 3 marks for each of the two engineering manufacturing industries, up to a total of 6 marks. The explanation must link the automation to the process required for the manufacture of the product.</p> <p>One mark can be awarded for the analysis and comparison of the processes, and another mark for the analysis and comparison of the level of automation for the selected products in each of the two different engineering manufacturing industries.</p> <p>Award up to 3 marks for the justification of the processes and level of automation used to manufacture a selected product from an engineering manufacturing industry.</p>

<b>Assessment focus LO.3</b>	
Mark Band 1–3 (0–17 marks)	<p>Up to 3 marks can be awarded for the project network analysis to show the critical path, the earliest start time and earliest finish time for most of the activities. Up to 2 marks can be awarded for the latest start time for most of the activities and up to 2 marks for the latest finish time for most activities. The decision about whether most of the times for the activities have been shown correctly or not depends on the amount of activities within the network. If the manufacture of the product is of a complex nature and involves a lot of activities it would be unfair to penalise a learner who can apply the process of calculating the times but makes some numerical or application errors, bearing in mind that this process involves cumulative calculations. The judgement to award marks should be based on the understanding the learner shows about these network times.</p> <p>Up to 3 marks can be awarded for a detailed production plan with all the information needed to manufacture a quantity of the same engineered product, as laid out in the content section. Award another mark if a third party could follow the plan. Up to 2 further marks may be awarded for a realistic schedule.</p> <p>Award 1 mark for the review and 1 mark for the justification of the revised production plan. Award 1 mark for the review and 1 mark for the justification of the revised schedule. It is expected that to gain full marks for mark band 3 the response would include suggestion on improvements to both.</p>

<b>Assessment focus LO.4</b>	
Mark Band 1–3 (0–10 marks)	<p>Up to 2 marks could be awarded for the production of appropriate charts to control output against a required standard and a further 2 marks for a chart to control the mean and variance. The charts should have clear control limits.</p> <p>Up to 3 marks can be awarded for a detailed analysis of the process control data (possibly in the form of a report) and for an explanation of how variations affect the process and product.</p> <p>Up to 3 marks can be awarded for the proposed course of action to alleviate unwanted process variations and for its evaluation. There must be evidence that some of the procedures of ISO 9001 have influenced the proposal.</p>

**Marking grid B**

<b>Assessment focus LO.4</b>	
Mark Band 1–3 (0–7 marks)	<p>Marks can be awarded for teamwork and the collection and sharing of sufficient, appropriate data from a manufacturing process. To achieve mark band 1 the learner will play a part in team activities and make an overall contribution. For mark band 2, the learner will take responsibility for their own actions and also accept a share of collective responsibility. To be eligible for mark band 3, the learner will show that they can play a key role in the team activity.</p>

## Approaches to assessment

It is most likely that tutors will want to set a number of separate tasks within the assignment that give learners opportunities to achieve each of the assessment foci. All of these could be completed on placement in suitable engineering manufacturing industries or in a well equipped workshop. Activities will need to be set within each task to give learners the opportunity to progress across the mark bands.

Task 1 could be a written ‘report’ or ‘oral presentation’ covering assessment focus 1. This will require the learner to explore the issues and explain the differences in traditional and modern manufacturing production systems in industries. At this level the learner will need to have sufficient knowledge and understanding of at least two different manufacturing systems to be able to explain the differences and to provide examples of typical products for each. For example, a visit to a metals industry plant and an aerospace manufacturer could provide the contrast in systems and products required. Choosing one industry that employs lean manufacturing techniques would be appropriate.

Task 2 could be a written ‘report’ or ‘oral presentation’ covering assessment focus 2. This could also be done on placement and possibly in the same industries used for 1 depending on the opportunities available. Alternatively, the task may direct learners towards two completely different industries so that they get a broader knowledge and experience of engineering manufacturing. This is likely to depend on the number and types of local industries and the level of access centres have to them.

Task 3 could be a written ‘report’ or ‘oral presentation’ covering assessment focus 3. Within the report or presentation will be the completed network, including the critical path and also a schedule and justification for mark bands 2 and 3 respectively. Activities will therefore need to be given that give learners opportunities to develop these requirements and suitable evidence.

Task 4 should be a ‘process portfolio’ covering assessment focus 4. An activity that directs the learner to collect process control data from a local industry or other local source needs setting. This activity must involve learners getting together, as a team, and making decisions about who will collect what data. This data should then be shared before each learner produces their own production charts. It is important that the evidence for teamwork is appropriately documented. The type of evidence expected must differentiate between the performances of each team member during collection and sharing activities. For example, evidence for assessment focus 4 mark band 1, 2 and 3 may take the form of a learner observation record sheet or tutor observation record to demonstrate that the learner did contribute to the collection and sharing of data within the team and fulfilled their own role within the team. Other supplementary evidence such as minutes of team meetings would also help consolidate this evidence. A learner statement simply saying ‘I contributed well to the team’ would be insufficient. The subsequent analysis of the data, and the proposal and evaluation of action to alleviate unwanted process variations do not have to be done in teams or in industry, although tutors may consider involving industrial partners in the assessment process.

The tasks can be devised for each assessment focus as indicated but where possible these should be linked to allow the holistic nature of the unit to come across. It is recognised, however, that this is not always possible. If a learner needs to retake any assignment, it is essential that different computer aided manufacturing systems, products and data be used to retain the validity of the assessment.

## Guidance for teaching this unit

### Delivery guidance

This unit is 60 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 20 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

The purpose of this unit is to give learners an opportunity to learn about new and innovative production systems and the processes that are now employed in this vibrant sector of the British economy. It is therefore imperative that learners have the opportunity to see and experience first-hand how industry has been transformed in recent years by modern manufacturing techniques, including automation and computer aided manufacturing. They will need to see how lean manufacturing is applied in different industries and be able to compare this with more traditional methods of manufacture.

Learning outcome 1 will provide an ideal starting point by introducing learners to industry and providing an insight into modern manufacturing techniques and the more traditional ones that are being replaced. The knowledge and understanding required for learning outcome 1 could be achieved during a short or extended placement in appropriate industries. The five engineering Sector Skills Councils (SSCs) represent all the different sectors of British engineering industry and consortia are encouraged to make use of as many of these as possible. The SSCs are committed to supporting the Diploma.

Similarly, learning outcome 2 provides another excellent opportunity for learners to learn about processes, many of which are now computer aided, and automation in an industrial setting.

Centres are strongly urged to engage industry when delivering and assessing learning outcomes 3 and 4. Tutors are encouraged to consider inviting industry partners to contribute to these specialised areas of production planning and control and quality control and quality assurance. It may be possible to invite industry specialists into the classroom or plan sessions around interactive video conferencing. What is key to these two learning outcomes is that the information and data presented to the learners, if possible, originates from industry.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	<p>Identifying coursework questions and problems to resolve.</p> <p>Exploring the issues and explaining the differences between traditional and modern manufacturing production systems in terms of number and volume of products manufactured, giving examples of typical products for each system. Assessment focus 1.</p> <p>Explaining the processes and level of computer-aided-manufacturing used to manufacture selected products in two different engineering manufacturing industries. Assessment focus 2.</p> <p>Producing a project network analysis to show the critical path for the manufacture of a quantity of the same engineered product.</p> <p>Working in a team and collect sufficient and appropriate data from a engineering process.</p>
<b>Creative thinkers</b>	<p>Producing a project network analysis to show the critical path for the manufacture of a quantity of the same engineered product.</p> <p>When producing appropriate charts to control the output against a required standard.</p>
<b>Reflective learners</b>	<p>Setting goals for the development of each of their assignments.</p> <p>Reviewing their progress against the completion of their assignments.</p>
<b>Team workers</b>	<p>Working in a team to collect sufficient and appropriate data from an engineering manufacturing process and producing appropriate charts to control the output against a required standard.</p> <p>Assessment focus 4.</p>
<b>Self-managers</b>	<p>Planning and organising the creation of their assignments for this unit.</p> <p>Dealing with time pressures and deadlines for the production of their assignments.</p> <p>Seeking advice and support from their peers and tutors when needed.</p> <p>Producing a project network analysis to show the critical path for the production of a quantity of the same engineered product.</p> <p>Assessment focus 3.</p>
<b>Effective participators</b>	<p>Producing a project network analysis to show the critical path for the production of a quantity of the same engineered product.</p> <p>Assessment focus 3.</p>

## Functional skills – Level 2

This unit provides opportunities for the development of some of the functional skills in English, particularly when writing documents communicating information, ideas and opinions when explaining the differences between traditional and modern production systems and the processes of automation. Learners will have opportunities to develop some of the functional skills in mathematics when making an initial model of a situation using suitable forms of representation, producing control charts and when interpreting and communicating the results of analysing the process control data to explain variations.

### Work experience

Learners can gain knowledge, skills and understanding for the learning outcomes during work placements and evidence can be collected to satisfy some of the summative assessment requirements. For example, assessment foci 1 and 2 could be addressed by the learner on placement in at least two different engineering industries so that research and information gathering is carried out first hand.

Whilst on placement learners could be given the basic information needed to complete assessment focus 3 mark bands 1 and 2, and develop a revised production plan for analysis and justification in mark band 3.

Assessment focus 4 requires learners to collect data from an engineering manufacturing process. This could be done whilst on placement or during a visit. Remember the data has to be collected whilst the learner is working as part of a team and needs to share the data.

### Reference material

Conner G – *Lean Manufacturing for the Small Shop* (SME, 2001) ISBN 9780872635203

Shingo S – *Mistake Proofing for Operators* (Productivity Press, 1997) ISBN 1563271273



# Unit 7: Innovative Design and Enterprise

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Principal Learning unit

Level 3

Guided Learning Hours: 60

Internally assessed

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## About this unit

There have been huge advances in technology in the last few years and it is constantly evolving. For example, cars have become increasingly more sophisticated and a modern family saloon easily outperforms sports cars from only a few years ago. Our lives are becoming ever more dependent upon computers but when your parents were young, they were regarded as little more than toys or only for use by large commercial organisations. All of the tremendous technological changes that have, and still are, taking place are due to a number of factors that involve the technologies themselves and the people who create and find uses for them in a wide variety of ways.

In completing this unit, you will be encouraged to investigate how our modern world is being shaped by a combination of innovation, the use of new and exciting technologies, leading edge design ideas and people with enterprise and an entrepreneurial spirit.

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## Learning outcomes

On completion of this unit, a learner should:

- LO.1. Know how a successful new product evolves
  - LO.2. Know about individuals who have become successful engineering entrepreneurs
  - LO.3. Understand how engineering activities impact on society and the environment
  - LO.4. Be able to produce or improve designs in an innovative way
  - LO.5. Know about opportunities for success when bringing a new product to market.
-

## What you need to cover

- |   |   |
|---|---|
| <b>LO.1 Know how a successful new product evolves</b>                                   | Learners will need to find out how a successful new product is a combination of innovation and invention in engineering design, new design and manufacturing technologies, market research and successful commercial development and marketing strategies.  |
| <b>LO.2 Know about individuals who have become successful engineering entrepreneurs</b> | Learners will need to find out about the identification of individuals who have become successful in engineering by virtue of innovation in leading edge product design, the use of new technologies in design and manufacture and innovation in sales and marketing techniques.  |
| <b>LO.3 Understand how engineering activities impact on society and the environment</b> | <p>Learners will need to investigate how engineering activities have an impact upon the social fabric of society and the sustainability of resources used, taking into consideration energy usage, pollution, material disposal.</p> <p>Learners will also investigate how new product design must meet accepted environmental standards.</p>   |
| <b>LO.4. Be able to produce or improve designs in an innovative way</b>                 | <p>Learners will need to be able to participate in the design of new products or improve existing products in an innovative way by developing skills in thinking for design purposes, problem solving, analytical thinking and using data to advantage.</p> <p>Learners will also consider how to present innovative designs or improvements to an interested audience.</p> <p>Learners will consider improvements to key product features such as aesthetics, function, materials, manufacture, environmental performance, eco-friendliness.</p>   |
| <b>LO.5. Know about opportunities for success when bringing a new product to market</b> | <p>You will develop skills in identifying commercial and technological opportunities and how they can be used to advantage</p> <p>You will need to consider benefits and applications of emerging technologies such as use of nanotechnology in fabricating devices with atomic or molecular scale precision and the applications this could be put to in improving the way in which we currently live through nanomachines, nanoelectronics and nanodevices, the likely first applications including computer science, communications and medical science.</p> <p>Learners will also understand how ideas can be legally protected, intellectual property rights, UK and international intellectual property legislation, patenting process, design registration, copyright and trade marking.</p> |
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## How you will be assessed

This unit will focus on innovation and design in relation to new products. As such you will be assessed through an assignment that will give you opportunities to demonstrate what you know about how products evolve, the different factors that have led to entrepreneurs' success, the impact engineering can have on society and the ways new products can be brought to market. You will also need to demonstrate that you can produce and present a new or improved design.

The unit will be assessed by your tutor who will set an assignment for you to complete. You are likely to be given one or more tasks which will cover all the material you have studied. At least some of these tasks will be set in the workshop and may relate to your work experience. Your tutor will give you opportunities to develop evidence. These opportunities could typically consist of five tasks.

Task 1 could cover the requirements for assessment focus 1 and could include activities for you to follow. You could therefore be asked to submit the evidence in a 'report' or carry out a 'presentation' or submit a 'case study'.

A second task could cover assessment focus 2 and would be a research type activity and the evidence will need to be submitted again in either a 'report' or carry out a 'presentation' or submit a 'case study'.

The third task could include written activities which cover the requirements of the assessment focus 3. As such evidence for task 3 should be in the form of a 'report'.

Task 4 could cover assessment focus 4 and will involve practical activities requiring you to produce designs and make a presentation. As such your evidence for this task will be submitted in a 'process portfolio' and where carried out a 'presentation'.

The final task could cover assessment focus 5 and will involve a research type activity exploring how new products are brought to market and why sometimes they succeed and sometimes they do not. As such your evidence for this task will be submitted in as a 'case study'.

## Marking grid A

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.1</b> Know how a successful new product evolves	Identifies two products that are recognised as being innovative, and compares them to traditional counterparts in terms of their design/operation, method of manufacture and marketing approach.  (0–4)	Identifies two products that are recognised as being innovative, compares them to traditional counterparts in terms of their design/operation, method of manufacture, marketing approach and explains the features of one of the products that has led to it being regarded as innovative.  (5–7)	Identifies two products that are recognised as being innovative, compares them to traditional counterparts in terms of their design/operation, method of manufacture, marketing approach and explains the features of one of the products that has led to it being regarded as innovative and the factors that have made it a success.  (8–10)	10
<b>LO.2</b> Know about individuals who have become successful engineering entrepreneurs	Identifies two successful entrepreneurial engineering-based individuals, and describes their route to success.  (0–4)	Identifies two successful entrepreneurial engineering-based individuals, describes their route to success and the key factors that led to their success.  (5–7)	Identifies two successful entrepreneurial engineering-based individuals, and describes their route to success, identifies the key factors that led to their success and analyses the reasons for their success in their careers.  (8–10)	10
<b>LO.3</b> Understand how engineering activities impact on society and the environment	Describes ways in which two engineering activities have had an impact on social activity, behaviour and the environment.  (0–4)	Explains ways in which engineering activity has had an impact on social activity and behaviour and how environmental issues have been addressed.  (5–7)	Uses a range of case studies to discuss different ways in which engineering activity has had an impact on social activity and behaviour, and different ways in which environmental issues have been addressed.  (8–10)	10

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.4</b> <b>Be able to produce or improve designs in an innovative way</b>	Produces a new design, or an improvement to an existing one, that displays innovation in terms of at least two key product features.  (0–4)	Produces a new design, or an improvement to an existing one, that displays innovation in terms of at least two key product features, explaining the value of the innovative features.  (5–6)	Produces a new design, or an improvement to an existing one, that displays innovation in terms of at least two key product features, explaining the value of the innovative features and the thinking and research processes that have led to the innovations.  (7–8)	8
<b>LO.5</b> <b>Know about opportunities for success when bringing a new product to market</b>	Describes how new products can be brought to market.  (0–6)	Describes how new products can be brought to market and reviews the ways in which two innovative products, one that was a commercial success and one that failed, were brought to market.  (7–10)	Describes how new products can be brought to market, reviews the ways in which two innovative products were brought to market, one that was a commercial success and one that failed and analyses the possible reasons for these two opposite outcomes.  (11–14)	14

### Marking grid B

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.4 Be able to produce or improve designs in an innovative way</b>	Gives a satisfactory presentation that partially engages the audience, conveys most of their design ideas and answers basic questions from the audience.  (0–4)	Gives an effective presentation that engages the audience, conveys their design ideas and answers a variety of questions from the audience.  (5–6)	Gives an effective and confident presentation that engages the audience, clearly conveys their design ideas and answers a wide variety of questions from the audience  (7–8)	8
<b>Total marks</b>				<b>(10+10+10+8+14+8) = 60</b>

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to confirm marks within the best fit approach. This section should be referred to only once the preliminary judgement has been made by the assessor and is used to guide the assessor as to placement within the mark band.

### Marking grid A

Assessment focus LO.1	
Mark Band 1 (0–4 marks)	<p>There is no credit simply for identifying an innovative product – the marks will come from the comparisons that are made with their traditional counterparts. For full marks all three features asked for in the grid must be addressed for each product, although these need not be balanced. A top of band response will typically make one or two good points against each feature, but a response that goes into a little less detail for one product could still get full marks if the other product is described in greater detail.</p> <p>A response that addresses only one product throughout can only get credit in this mark band, no matter how detailed it might be.</p>
Mark Band 2 (5–7 marks)	<p>For full marks in this band responses must go into some detail about the two chosen products to explain what made them innovative. Different success factors are described but they are likely to be considered separately from each other.</p> <p>Marks lower in the band will be for the response which explains some of the key features but which don't bring out the innovative nature explicitly, or those which have addressed only some of the success factors.</p>
Mark Band 3 (8–10 marks)	<p>Responses in this band will look in detail at the innovative features, bringing in some analysis that might consider how innovative they were ('quantum leap' or a refinement of existing technology, for example) or whether the innovation came from large teams with huge resources (eg i-Pod) or a single person (eg Trevor Bayliss' wind-up radio). The other distinguishing feature is an understanding that the factors leading to success (design/operation, manufacturing technology and marketing) all combined rather than acted separately.</p> <p>Responses will need either some analysis, or an explicit understanding of the linking of the success factors, to start earning marks in this band.</p>

<b>Assessment focus LO.2</b>	
Mark Band 1 (0–4 marks)	<p>There is no credit simply for naming appropriate individuals; the credit comes from describing their routes to success. This might cover some traditional features like education and training, but the emphasis should be on what has led them to their success – perhaps by considering early breakthrough developments (eg James Dyson’s ‘ballbarrow’) and showing how that led through to later, higher profile developments. A good response would probably highlight three or four key milestones in an individual’s rise to fame.</p> <p>Strong responses about one individual can offset weaker responses about the second. Any response that relates to just one person throughout will only be eligible for marks in this band.</p>
Mark Band 2 (5–7 marks)	<p>For full marks the learner should have initially chosen entrepreneurs with a reputation for innovation and then researched in some depth to identify the ideas or actions that began the rise to fame (and possibly wealth). The band 2 response goes beyond that for band 1 by being a fuller, more detailed description of the individuals’ pathways to success. Within this fuller picture the learner can accurately pick out the key milestones that had the greatest effect in establishing the individual’s reputation.</p> <p>Marks lower in the band will be for the responses which describe in detail most of the milestones but which don’t bring out those which have had the greatest impact, or the responses which have addressed only some of the success factors.</p>
Mark Band 3 (8–10 marks)	<p>For full marks there do not necessarily need to be more ‘facts’ about the individual than for band 2, but there will be a real understanding of what the events, people and influences were that shaped their success. In addition to describing in detail the path of the chosen entrepreneurs, there is analysis that looks at the impact of the key factors to comment on how each was important.</p> <p>Responses will need some explicit analysis of such moments in the career of one of their chosen entrepreneurs to start earning marks in this band.</p>

<b>Assessment focus LO.3</b>	
Mark Band 1 (0–4 marks)	<p>Learners will need to describe social, behavioural and environmental issues to get full marks. It is likely that there will be two or three well-made points about each aspect but a response that was more strongly weighted towards one aspect or the other could still get full marks as long as the other aspects were considered in some meaningful way. In this band the learner may take something of an unbalanced view and see these impacts as essentially negative for example.</p> <p>At the lower end of this band responses will be thinner, with perhaps only one or two points made about each topic, and possibly in the form of generalised statements. Learners ought to back up their comments with reference to actual activities, even if they are not presented as case studies.</p> <p>The response that focuses entirely on social, behavioural or environmental aspects will be limited to credit in this band, no matter the detail that is given.</p>
Mark Band 2 (5–7 marks)	<p>At band 2 learners should be starting to take a more balanced view of the impacts on social, behavioural and environmental activities, with a recognition that these can be both positive and negative, and the highest mark should be reserved for those who demonstrate this. Responses should be explanatory in nature, rather than descriptive, so that the reason for the impact is made clear, as well as the description of the impact that would on its own have been a band 1 approach.</p> <p>At the lower end of this band responses may have only some of the points explained, and may be imbalanced. Strong explanations that are left as generalisations about ‘engineering’ in general without being related to actual case studies should not get beyond the bottom of this band.</p>
Mark Band 3 (8–10 marks)	<p>This band is characterised by the response built around some strong case studies which between them address a range of social and environmental issues. The learner has discussed these issues to look at them from different angles, demonstrating, for example, an understanding that what may be a negative impact for one constituency could be positive for others, and that few impacts are entirely ‘good’ or ‘bad’. Alternatively, the response may challenge perceived wisdom. The ‘discuss’ element is important in getting access to this band; responses that are just very good explanations are very good band 2 responses. It needs only some ‘discussed’ points to get into the lower end of this band, but at the top end this must be the approach that dominates.</p>

<b>Assessment focus LO.4</b>	
Mark Band 1 (0–4 marks)	The learner presents a description of one or more innovations that have been made to an existing product, or designed into something new. One creative and well-developed innovative improvement could be enough to set the learner on the way to full marks in this band, but it would need to be supported by at least one other smaller innovation, identified but not so well developed. Alternatively there might be two equally well-developed and described ideas. The features should include any two from a range including aesthetics, function, materials, manufacture or environmental performance.
Mark Band 2 (5–6 marks)	To achieve marks in this band the design will be innovative in at least two ways from the features listed in band 1 and the innovations will be explained to show how they add value to the product. Learners getting full marks for this aspect will have explained both ways in which innovation has been achieved, while marks lower in the band will have less convincing explanation, or a mix of description and explanation. The need to explain should draw out the creative potential in learners, and this should be rewarded.
Mark Band 3 (7–8 marks)	For credit in this band, learners will be going beyond explanation of the value of their design to explain the creative process behind it. Some acknowledgement of this is essential to start scoring in this band, no matter how good the innovations might otherwise be. For full marks on the content side, there will be a clear explanation of at least two of the processes that led to the innovations being designed.

<b>Assessment focus LO.5</b>	
Mark Band 1 (0–6 marks)	<p>Responses at this level are characterised by making general points about bringing a product to market. There may be some references to actual products, but they are dropped in to support the generalisations, rather than being a case study around which the response is built.</p> <p>For full marks the learner should recognise the range of activities involved, including most stages as testing the market, funding, competitive manufacturing, sales and marketing and legal protection of new ideas. Fewer marks will be available to the learner with a narrow range, although good case study-based coverage of just two or three stages could get close to full marks in this band.</p>
Mark Band 2 (7–10 marks)	<p>For full marks at this level the response should be based around two case studies, with a recognition of the breadth of activity, although inevitably there will be more detail about certain aspects, such as the marketing campaign or the quality of the product, than others such as the legal protection of the idea. For band 2 the ‘review’ of the two studies does not expect great depth, with more emphasis on breadth and, at the top of the band, some explanation for the success/failure or for the way in which it was brought to market.</p> <p>Marks lower in the band will be appropriate for case studies lacking a bit in breadth, or being purely a description of what happened.</p>

<b>Assessment focus LO.5 (continued)</b>	
Mark Band 3 (11–14 marks)	Band 3 requires some analysis of the reasons for success/failure. The bulk of the response will be good case study description as for Level 2, but the quality of the reasoning to explain the success/failure will determine access to the top marks. One strong evaluative comment about each outcome could be enough, although others will get there with two or three simpler reasons for each outcome.

**Marking grid B**

<b>Assessment focus LO.4</b>	
Mark Band 1-3 (0–8 marks)	<p>Presentations may be oral, supported by slides, sound effects, artefacts etc, or could be wall-mounted displays with sketches, plans, or annotated photographs, multi-media displays or other appropriate forms.</p> <p>To be eligible for mark band 1 the learner will give a basic presentation which conveys most of their design ideas. They will be able to answer some straight forward questions from the audience. For mark band 2 the learner will be able to engage the audience when presenting their design ideas. They will be able to answer a range of question from the audience. For mark band 3 the learner will give an assured and confident presentation covering all aspects of their design ideas, engaging the audience throughout. They will be able to answer a range of questions from the audience.</p>

## Approaches to assessment

The guidance below suggests five tasks in one assignment to cover the requirements of the unit, but there is scope for combining some of these. Taking a holistic approach, demonstrating the links between the different learning outcomes, is recommended but will not be possible in all contexts.

Task 1 could cover assessment focus 1, for which learners will need to show that they have an understanding of the stages that a new product has to progress through from original idea to being a successful product in the marketplace. This could be accomplished by a written report or PowerPoint presentation relating to the introduction of well-known products or, alternatively, by case studies of specific products. As such the evidence could be submitted in either a ‘report’, ‘presentation’ or ‘case study’

Task 2 will require learners to identify a number of successful entrepreneurs and chart their success to achieve assessment focus 2. Case studies of successful engineering-based entrepreneurs should adequately meet this requirement, with the evidence likely to be submitted as a ‘report’ or ‘presentation’.

Task 3 could cover assessment focus 3 and will require learners to demonstrate an understanding of how engineering activities can impact on society in general and more specifically the environment which we all share. Learners will need to be given opportunities not only to describe ways in which two engineering activities have made an impact but also to explain how environmental issues have been addressed and what the potential environmental benefits are. The evidence would need to be submitted in a ‘report’.

Task 4 could cover assessment focus 4. This could be the most challenging part of the unit, but it also carries a higher weight of marks. Learners will need to take a very practical approach, selecting products that are generally recognised as being traditional in design or technology and make improvements in their performance, appearance or method of manufacture, that utilise new technology, materials or processes. Alternatively, learners could choose to create a new design for an existing but traditional product or a completely new product. Selection of products or ideas will be important and care needs to be taken as an over-ambitious idea could need more time than would normally be expected. However, the unit is for learners with ideas so they must not be afraid to develop radical thinking.

The presentation aspect of the task is important and will be the way that the learner presents their evidence – in effect, makes a pitch to ‘sell’ the value of their innovation(s) – as well as attracting credit for their presentation skills. It replicates an unavoidable part of the entrepreneur’s work, and learners might like to include some episodes of ‘Dragon’s Den’ as part of their preparation for this activity. The audience to which the learner pitches could be composed of members of the teaching group, school or college staff, local employers or a mix of these people. If it is an oral presentation there should be about 5-10 minutes for the presentation with an opportunity for answering two or three questions afterwards. Learners presenting their designs in other ways should also have the opportunity to respond to questions.

Task 5 will cover assessment focus 5 and will require learners to demonstrate their awareness of the stages involved in bringing a new product to market, particularly the problems that entrepreneurs face in persuading others that their ideas or products will not only work, but also be successful. The requirement for this assessment focus could typically be achieved by carrying out case studies of successful and innovative products for which ample evidence and sources of information should be available. As such, the evidence would need to be submitted as a ‘case study’.

## Guidance for teaching this unit

### Delivery guidance

This unit is 60 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 20 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

The teaching of this unit should concentrate on the factors that lead to enterprise, creativity and innovative thinking and could be classified into three areas: innovation, product design and development and taking advantage of developments.

When delivering learning outcome 1, learners should gain an understanding of the stages that a new product has to progress through. This could be done through the use of case studies or learners could be encouraged to research well-known or specific products such as a well known type of vacuum cleaner for example.

For learning outcome 2 case studies of successful engineering-based entrepreneurs should be used, ideally those with a reputation for new and innovative ideas and products. Learners should be encouraged to research and identify the particular ideas, actions or products that set each individual entrepreneur on the road to success.

The use of catalogued examples of the effects that engineering can or has had on social and environmental issues could be useful in when delivering learning outcome 3. If learners choose which specific engineering activities they wish to research, guidance should be given to ensure that the topics chosen have had positive and negative effects across social activity and behaviour and on the environment.

Learning outcome 5 gives an opportunity for learners to gain an awareness of the process of bringing a new product to market. Teaching should concentrate on the introduction of commercial and technological opportunities in terms of testing the market, funding, competitive manufacturing, sales and marketing and legal protection of new ideas. They should also know about how ideas can be legally protected.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	<p>Assessment foci 1, 2, 3 and 5 require research to be carried out in order to gather the information that would enable the learner to achieve them. As this is not intended to be a group activity, it would require a learner to identify and use the information from a variety of sources.</p> <p>Identifying two products that are recognised as being innovative, comparing them to traditional counterparts in terms of their design/operation, method of manufacture, marketing approach and explaining the features of one of the products that has led to it being regarded as innovative. Assessment focus 1.</p>
<b>Creative thinkers</b>	<p>Producing a new design, or an improvement to an existing one that displays innovation in terms of at least two product features. Assessment focus 4.</p>
<b>Reflective learners</b>	<p>Goals and targets need to be set if the assignments are to be completed successfully and the ability to review progress and make adjustments where necessary requires this skill.</p>
<b>Team workers</b>	<p>Not present in this unit.</p>
<b>Self-managers</b>	<p>Research requires a disciplined and structured approach to successful completion of the task in hand. Assessment foci 1, 2, 3, and 5 requires learners to display this skill.</p> <p>Ensuring that assignments are completed to a timescale also requires this skill and applies to all assessment foci.</p>
<b>Effective participators</b>	<p>Producing a new design that improves upon a similar product or improves existing design in at least two product aspects. Assessment focus 4.</p>

## **Functional skills – Level 2**

This unit provides opportunities for the development of some of the functional skills in English, particularly when learners are writing documents that describe and explain innovative products and ideas. Learners will develop skills in presenting and justifying their ideas.

### **Work experience**

The use of work placements would be ideal for this unit, which would help show the importance of design and innovation to commercial success. If work placements are available, assignments based around the placement would be beneficial. However, it is appreciated that suitable placements are not always available and in-house assignments are just as acceptable.

### **Specialist resources**

Learners will require internet access for research and video resources might also be useful, especially for learning outcome 2. Design software might also be used although this is not essential.

# Unit 8: Mathematical Techniques and Applications for Engineers

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Principal Learning unit

Level 3

Guided Learning Hours: 60

Externally assessed

(58.75 hours learning time and 1.25 hours for assessment)

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## About this unit

Mathematics is an essential tool used by engineers every day. An understanding of mathematics and an ability to apply it to the solution of common engineering problems is a skill that you need to develop during your study of engineering. Typical applications of mathematics involve determining the maximum load that can be applied to a beam, calculating the amount of energy required to operate a hoist, finding the distance travelled by a vehicle in a given time, and determining the power delivered by an amplifier to a loudspeaker. The unit will not just concentrate on mathematical theory, as you will be introduced to a variety of useful techniques that will help you solve real engineering problems.

The unit provides the essential mathematical knowledge that you will need in order to successfully study several of the other Level 3 units, such as *Unit 1: Investigating Engineering Business and the Environment*, *Unit 3: Selection and Application of Engineering Materials*, *Unit 4: Instrumentation and Control Engineering* and *Unit 9: Principles and Application of Engineering Science*. You will also need to demonstrate a proficiency in mathematics if you are planning to continue your study of engineering at a higher level.

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## Learning outcomes

On completion of this unit, a learner should:

- LO.1. Know how to use algebraic methods to solve engineering problems
  - LO.2. Be able to use trigonometric methods to solve engineering problems
  - LO.3. Be able to use statistical methods to display engineering data
  - LO.4. Know how to apply elementary calculus techniques to solve engineering problems.
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## What you need to cover

### LO.1 Know how to use algebraic methods to solve engineering problems

Learners will need to know about indices and logarithms, laws of indices ( $a^m \times a^n = a^{m+n}$ ,  $\frac{a^m}{a^n} = a^{m-n}$ ,  $(a^m)^n = a^{mn}$ ), laws of

logarithms ( $\log a + \log b = \log ab$ ,  $\log a^n = n \log a$ ,  $\log a - \log b = \log \frac{a}{b}$ ), eg common logarithms (base 10), natural logarithms

(base  $e$ ), exponential growth and decay. They will need to be able to solve engineering problems, eg growth of voltage in a capacitor, decay of current in an inductor, radioactive decay, Taylor's tool life equation, hysteresis loss in a magnetic core, ratio of tensions for a flat belt or vee belt drive.

Learners will need to know about linear equations and straight line graphs, linear equations, eg  $y = mx + c$ ; straight line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line), simultaneous solution of linear equations. They will need to be able to solve engineering problems, eg determination of temperature coefficient, calculation of linear thermal expansion, variation of voltage with current for a resistor, variation of inductive reactance with frequency, load/extension and stress/strain (within linear range), distance/time graphs, force and acceleration.

Learners will need to know about factorisation and quadratics, be able to multiply expressions in brackets by a number, symbol or by another expression in a bracket; by extraction of a common factor, eg  $ax + ay$ ,  $a(x - 1) + b(x - 1)$ ; by grouping, eg  $ax - ay + bx - by$ ; quadratic expressions, eg  $a^2 + 2ab + b^2$ ; roots of an equation, eg quadratic equations with real roots by factorisation,

and by the use of formula,  $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ . They will need

to be able to solve engineering problems, eg determination of fabrication of enclosures, filling a tank at different rates from two sources, calculation of impedance of an AC load, Brinell hardness number, work done and power transmitted by a constant torque, power transmitted by a belt drive, coefficient of superficial expansion, coefficient of cubic expansion, variation of resistance with temperature, characteristic gas equation, simple harmonic motion, solution of problems involving cables, wires and catenaries.

**LO.2 Be able to use trigonometric methods to solve engineering problems**

Learners will need to know about circular measure and radian; degree measure to radians and vice versa; angular rotations (multiples of  $\pi$  radians); problems involving areas and angles measured in radians; length of arc of a circle ( $s = r\theta$ ); area of a sector ( $A = \frac{1}{2} r^2\theta$ ); and be able to solve engineering problems, eg solution of problems involving shafts, pulleys, material removal rates, curved surfaces, angular velocity, angular acceleration, angle of lap of a belt drive.

Learners will need to know about triangular measurement and functions (sine, cosine and tangent); sine/cosine wave over one complete cycle; graph of  $\tan A$  as  $A$  varies from  $0^\circ$  and  $360^\circ$  ( $\tan A = \sin A/\cos A$ ); values of the trigonometric ratios for angles between  $0^\circ$  and  $360^\circ$ ; periodic properties of the trigonometric functions; the sine and cosine rule. They will need to be able to solve engineering problems, eg calculation of the phasor sum of two alternating currents, resolution of system of coplanar forces, angle of elevation and angle of depression, power factor of an AC load, power factor correction, structures, sloping sides, guys and stays, calculation of angle of visibility of a satellite.

Learners will need to know about mensuration: standard formulae to solve surface areas and volumes of regular solids, eg volume of a cylinder =  $\pi r^2h$ , total surface area of a cylinder =

$$2\pi rh + 2\pi r^2, \text{ volume of sphere} = \frac{4}{3}\pi r^3, \text{ surface area of a}$$

$$\text{sphere} = 4\pi r^2, \text{ volume of a cone} = \frac{1}{3}\pi r^2h, \text{ curved surface area}$$

of cone =  $\pi r \times$  slant height. They will also need to solve engineering problems, eg calculation of surface area and volume of various types of storage vessel, dimensional specification of enclosures, estimating cost of materials, application of conformal and other coatings, determination of radiated power density, illumination of a surface, cone of acceptance for an optical fibre.

**LO.3 Be able to use statistical methods to display engineering data**

Learners will need to know about data handling and data represented by statistical diagrams, eg bar charts, pie charts, frequency distributions, class boundaries and class width, frequency table; variables (discrete and continuous); histogram (continuous and discrete variants); cumulative frequency curves; binomial expansion. They will also need to solve engineering problems, eg cost analysis of an engineered product or service, time analysis of an engineered product or service, analysis of production variance, presentation and illustration of measured data, stock and supply levels

Learners will need to know about statistical measurement: arithmetic mean; median; mode; discrete and grouped data; they will also need to solve engineering problems, eg mean time to failure (MTTF) and mean time to repair (MTTR), analyses of production data, tolerance of a batch of resistors, quality assurance.

**LO.4 Know how to apply elementary calculus techniques to solve engineering problems**

Learners will need to know about differentiation and differential coefficient; gradient of a curve  $y = f(x)$ ; rate of change; Leibniz notation ( $\frac{dy}{dx}$ ); differentiation of simple polynomial functions, exponential functions and trigonometric functions. They will also need to solve engineering problems, eg determination of acceleration from a velocity/time function, determination of resistance from a voltage/current function, problems involving growth and decay, radioactivity, cooling curves, determination of induced e.m.f. from an applied current/time function, determination of current in a capacitor from an applied voltage/time function, determination of minimum dimensions for a storage vessel or enclosure, determination of flow rate and liquid level in a tank

Learners will need to know about integration and integration as reverse of differentiating basic rules for simple polynomial functions, exponential functions and trigonometric functions; indefinite integrals; constant of integration; definite integrals; limits; evaluation of simple polynomial functions; area under a curve, for functions such as  $y = x(x - 3)$ ,  $y = x^2 + x + 4$ . They will also need to solve engineering problems, eg calculation of distance travelled for a given velocity/time function, determination of energy stored for a given power/time function, determination of power in an AC circuit, work done over a distance, braking distance for a vehicle, moment of inertia of a disc, radius of gyration, work done in expansion.

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## Learning outcomes and assessment criteria for each unit

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Know how to use algebraic methods to solve engineering problems	<p>Simplify and evaluate expressions involving the use of indices.</p> <p>Solve a linear equation by plotting a straight line graph from given data and use it to deduce the gradient, intercept and equation of the line.</p> <p>Solve problems involving logarithms.</p> <p>Solve problems involving exponential growth and decay.</p> <p>Use factorisation to simplify mathematical expressions.</p> <p>Solve quadratic equations by factorising or by using the formula method.</p>
LO.2	Be able to use trigonometric methods to solve engineering problems	<p>Define and determine the sine, cosine and tangent of a given angle in a given right-angled triangle and solve problems involving right angled triangles.</p> <p>Use standard formulae to find surface areas and volumes of regular solids.</p> <p>Sketch trigonometric functions over a complete cycle and solves trigonometric equations.</p> <p>Convert radians to degrees and degrees to radians and solve problems involving circular measure.</p> <p>Apply the sine and cosine rules to the solution of trigonometric equations.</p> <p>Solve problems involving angular motion, converting between units expressed in terms of revolutions per second, revolutions per minute and radians per second (as appropriate).</p>
LO.3	Be able to use statistical methods to display engineering data	<p>Generate ideas to produce appropriate statistical diagrams, histograms and frequency curves for a given set of statistical data.</p> <p>Determine the mean, median and mode for a given set of statistical data.</p> <p>Explain the significance of mean, median and mode for a given set of statistical data as a measure of central tendency.</p>

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.4	Know how to apply elementary calculus techniques to solve engineering problems	<p>Determine the gradient of a curve by constructing a tangent at different points. Identify turning points (maximum, minimum and inflexion) and infers that the gradient will be zero at such a point.</p> <p>Apply the basic rules of calculus to a polynomial or trigonometric expression in order to obtain the derivative function.</p> <p>Apply the basic rules of calculus to a polynomial or trigonometric expression to obtain the integral function.</p>

## How you will be assessed

This unit is externally assessed by means of a written paper containing approximately six to eight compulsory questions. All of the questions will involve the use of appropriate mathematical modelling techniques to solve real engineering problems, such as those involving force, mass, acceleration and energy or voltage, current, resistance and power. You will sit the assessment under formal examination conditions and the assessment must be completed within a time of 1 hour 15 minutes. You may use a basic scientific calculator (eg Casio model FX-83ES) during the assessment. Please confirm with your tutor that the calculator you wish to use is suitable for this purpose.

## Guidance for teaching this unit

### Delivery guidance

This unit provides the essential mathematical underpinning knowledge that learners will require in order to fully understand the work introduced in the other Level 3 units. Learners need to be introduced to a wide range of mathematical modelling techniques sufficient to provide a basis for the solution of a wide range of engineering problems involving, for example, moments and centres of mass, kinematics and Newton's laws of motion. The unit is also designed to provide a sound basis in mathematical concepts for learners wishing to progress beyond Level 3. To encourage and enhance the development of mathematical skills, it is essential that learners appreciate the relevance of this unit in the context of engineering as a whole.

For this reason, it is important that mathematical theory is contextualised as far as possible. In order to achieve this, examples and problems should be based on those that occur in a real engineering context. For example, when learners are applying calculus techniques they should be made aware that acceleration,  $a$ , is simply the rate of change of velocity with time,  $\frac{dv}{dt}$ , and that the distance travelled,  $s$ , is simply the area under the function,  $\int v dt$ .

It is expected that most learners will be concurrently studying other Level 3 units, such as *Unit 1: Investigating Engineering Business and the Environment*, *Unit 3: Selection and Application of Engineering Materials*, *Unit 4: Instrumentation and Control Engineering* and *Unit 9: Principles and Application of Engineering Science*. These units (as well as many other Level 3 units) provide ample opportunity to use mathematics as a tool in problem solving. For example, in *Unit 3: Selection and Application of Engineering Materials*, learners will be required to plot graphs of stress against strain in order to determine the modulus of elasticity of a material.

Not only will real data be available to learners as a result of practical work but the link can directly be made to the use of graphical techniques (such as constructing a tangent to a graph in order to determine its slope or gradient). Another naturally occurring example is that of analysing production data in conjunction with learners' investigation of engineering businesses in *Unit 1: Investigating Engineering Business and the Environment*. Here again, learners should have ample data from which to develop mathematical skills. In this case, they will be able to use different techniques to present statistical data and also to analyse the data, determining median and mode and evaluating their results.

Prior to embarking on this unit, learners should be able to demonstrate proficiency in basic mathematical concepts and also in the use a basic electronic scientific calculator to carry out a variety of functions.

The learning outcomes would be best delivered in order. In particular, learners should develop proficiency in algebraic manipulation at an early stage. These skills will be essential in developing proficiency in the other learning outcomes. Once learners have mastered basic algebraic manipulation techniques in learning outcome 8.1 they can apply these skills in 8.2 when solving circular and triangular measurement problems.

Learners should be given plenty of practice when drawing graphs from 8.1 and sketching trigonometric functions in 8.2. Learning outcome 8.3 should involved real engineering data as far as possible. For example, instead of using generalised data (such as height of learners) centres should use meaningful data that learners will recognise in an engineering context. A good example would involve learners making measurements on given batches of 50 resistors. They would then have first-hand experience of collecting and presenting typical engineering data relevant to work carried out previously at Level 1 (Unit 6) and Level 2 (Unit 5).

In learning outcome 8.4, learners should be introduced to calculus techniques based on typical engineering applications. Learners frequently find this topic difficult and it is therefore essential that they appreciate the practical application of calculus rather than merely seeing it as a mathematical hurdle and a potential barrier to future learning.

It is important to note that the external assessment for this unit will require learners to apply appropriate mathematical modelling techniques to the solution of engineering problems. Learners will be expected to apply their knowledge and understanding of mathematics to the solution of a range of practical problems, for example, those involving exponential growth of voltage in a capacitor undergoing charge, change in momentum of a body experiencing an impulse force, moments and centres of mass of a body, power factor and phase angle of a reactive load in an AC circuit. Learners should, at all times, be encouraged to relate their knowledge and understanding of mathematical techniques to the real world of engineering. Close links should therefore be made between this unit and *Unit 9: Principles and Application of Engineering Science*, and tutors should actively look for opportunities to show how mathematical modelling can be used as a tool to solve real engineering problems.

In the external assessment for this unit learners are required to follow the current regulations for calculator use as in GCEs, available from [www.jcq.org.uk](http://www.jcq.org.uk).

**Guidance for the delivery of personal, learning and thinking skills (PLTS)**

Although PLTS are not identified within this unit as an inherent part of the assessment criteria, there are opportunities to develop a range of PLTS through various approaches to teaching and learning. (*Annexe B* of this document lists the personal, learning and thinking skills and their elements.)

Skill	When learners are ...
<b>Independent enquirers</b>	<p>Applying mathematical modelling techniques to the solution of engineering problems (for example when using integral calculus to determine the distance travelled by a projectile).</p> <p>Determining the gradient of a curve by constructing a tangent at different points. Identifying turning points (maximum, minimum and inflexion) and infers that the gradient will be zero at such a point. Assessment focus 4.</p>
<b>Creative thinkers</b>	<p>Making inferences from mathematical data (for example recognising that a function is periodic; identifying maximum and minimum rates of change; identifying short-term and long-term trends); solving equations involving substitution and factorisation techniques.</p> <p>Producing appropriate statistical diagrams, histograms and frequency curves for a given set of statistical data. Assessment focus 3.</p>
<b>Reflective learners</b>	<p>Checking that answers to numerical problems are realistic and within an appropriate range; evaluating results of statistical analyses.</p> <p>Producing appropriate statistical diagrams, histograms and frequency curves for a given set of statistical data. Assessment focus 3.</p>
<b>Team workers</b>	Not present in this unit.
<b>Self-managers</b>	Planning and organising their work.
<b>Effective participators</b>	<p>Making a positive contribution to class activities, such as class or group problem solving.</p> <p>Defining and determining the sine, cosine and tangent of a given angle in a given right-angled triangle and solving problems. Assessment focus 2.</p> <p>Determining the gradient of a curve by constructing a tangent at different points. Identifying turning points (maximum, minimum and inflexion) and infers that the gradient will be zero at such a point. Assessment focus 4.</p>

## Functional skills – Level 2

This unit provides opportunities for developing some of the functional skills in mathematics. Learners will develop proficiency in using a basic scientific calculator, including an ability to enter and manipulate data, when they are solving problems with numerical solutions. Learners will develop skills in presenting data in different forms when analysing statistical data. Learners will also develop proficiency in plotting graphs of mathematic functions.

### Work experience

Learners will require access to an approved scientific calculator that supports the direct entry of mathematical notation such as fractions, roots, etc. The approved calculator is not required to provide programmable features nor should it have a graphical display. Learners should be encouraged to develop proficiency using this calculator and it should be available for use during the external assessment. The currently approved calculator is the Casio fx-83ES which is widely available at low cost.

### Reference material

Bird J – *Engineering Mathematics* (Newnes, 2007) ISBN 0750657766

Bird J – *Basic Engineering Mathematics* (Newnes, 2005) ISBN 0750665750

Tooley M and Dingle L – *BTEC National Engineering* (Butterworth-Heinemann, 2002) ISBN 0750651660

# Unit 9: Principles and Application of Engineering Science

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## Principal Learning unit

Level 3

Guided Learning Hours: 90

Internally assessed

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### About this unit

Many of the goods and services that we use are made available partly due to engineers applying nothing more than basic scientific principles and concepts. For example, the energy that we need to provide light and warmth is often generated many hundreds of miles away from where we live and then transmitted over long distances using high voltages and overhead cables. Without this system every town would need to have its own local power station which would not only be ugly and environmentally unfriendly but also inefficient and inconvenient in the event of a breakdown.

This unit provides the essential scientific principles that will help in your study of some other Level 3 units, such as *Unit 3: Selection and Application of Engineering Materials*, *Unit 4: Instrumentation and Control Engineering* and *Unit 7: Innovative Design and Enterprise*. A good understanding of scientific principles is also an essential prerequisite if you are planning to continue your study of engineering at a higher level.

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### Learning outcomes

On completion of this unit, a learner should:

- LO.1. Be able to apply mechanical principles to determine the effects of forces in engineering systems
  - LO.2. Be able to apply mechanical principles to determine the effects of motion, work and energy transfer in engineering systems
  - LO.3. Be able to apply electrical principles to determine the effects of electric charge and current and determine the voltage, current, resistance and power in electrical circuits
  - LO.4. Be able to apply the principles of heat and thermodynamics to determine the effects of expansion and compression of gases and energy transfer in engineering systems
  - LO.5. Know about the principles of chemistry and the effects of chemical processes and reactions
  - LO.6. Be able to apply the principles of fluid dynamics to determine the effects of viscosity and the forces acting in hydrostatic systems.
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## What you need to cover

- LO.1 Be able to apply mechanical principles to determine the effects of forces in engineering systems**
- Learners will need to know about coplanar force systems and the related underpinning concepts, eg matter, mass, weight, density ( $m = \rho V$ ), conditions for static equilibrium, vector representation of forces (resultant, equilibrant), concurrent force systems, graphical solution of force systems (triangle of force for a balanced three coplanar force system and polygon of force for an unbalanced coplanar force system containing three or more forces).
- Learners will also need to know about loaded systems and loading of beams, eg concentrated point loads, uniformly distributed loads (UDL), weight of beam represented as a point load at the centre of gravity of the UDL/beam; conditions for static equilibrium; determination of beam reactions due to loading.
- LO.2 Be able to apply mechanical principles to determine the effects of motion, work and energy transfer in engineering systems**
- Learners will need to understand linear motion and be able to solve engineering problems using linear equations of motion including  $v = u + at$ ,  $s = \frac{1}{2}(u + v)t$ ,  $s = ut + \frac{1}{2}at^2$ ,  $v^2 = u^2 + 2as$  and graphs of linear displacement against time, velocity against time from given data. They will also need to be able to solve engineering problems, eg determine the action and reaction of applied forces through the application of Newton's first, second and third laws of motion, using principles of linear momentum and conservation of momentum.
- Learners will need to learn about angular motion and angular displacement, be able to solve engineering problems using angular equations of motion, eg  $\omega_2 = \omega_1 + \alpha t$ ,  $\theta = \frac{1}{2}(\alpha_1 + \alpha_2)t$ ,  $\theta = \omega_1 t + \frac{1}{2}\alpha t^2$ ,  $\omega_2^2 = \omega_1^2 + 2\alpha\theta$  and graphs of angular displacement against time, angular velocity against time from given data. Learners will need to be able to solve engineering problems, eg torque ( $T = Fr$ ,  $T = I\alpha$ ), angular momentum and conservation of momentum.
- Learners will also need to know about mechanical work, energy, power and friction and be able to solve engineering problems involving the work-energy relationship, gravitational potential energy (PE), kinetic energy (KE), conservation of energy, eg  $KE + PE = \text{a constant}$ , work done and energy transfer. They will also need to understand the nature of friction, application of friction as a retarding force against linear translation ( $F_r = \mu N$ ) and be able to solve engineering problems involving static and kinetic coefficient of friction.
- LO.3 Be able to apply electrical principles to determine the effects of electric charge and current and determine the voltage, current, resistance and power in electrical circuits**
- Learners will need to learn about the nature of electricity, charges at rest and in motion, electric current as flow of charge and be able to solve related engineering problems, eg the relationship between charge, current and time, eg  $Q = It$ .
- Learners will need to understand electrostatics and the nature of an electric field in terms of the motion of a free positive charge and will need to be able to solve related engineering problems, eg the relationship between charge and electric potential, electric field strength (potential gradient =  $V/d$ ). They will need to know about the nature of electric charge, electric field patterns between isolated bodies with similar and dissimilar polarities, electric field pattern between two parallel metal plates and be able to solve engineering problems involving the force between two charges, eg  $F = \frac{Q_1 Q_2}{kd^2}$ .

Learners will need to know about magnetism and the nature of a magnetic field in terms of the motion of a free north pole and be able to solve related engineering problems, eg the field around a current carrying conductor, field around a single turn loop, field around a solenoid. They will need to know about the comparison of the field around a solenoid with that of a permanent bar magnet and be able to solve engineering problems, eg the force around a current carrying conductor,  $F = B I l$ ; electromagnetic induction, induced electromotive force (emf); coupled inductors; Lenz's and Faraday's laws. They should also be able to explain the basic principles and construction of generators and motors.

Learners will need to gain an understanding of DC circuits and the definition of potential difference and emf. They will solve engineering problems involving specific resistance (resistivity) and resistance, eg  $R = \rho l/A$ , voltage and resistance in a simple circuit consisting of a source of emf and a single resistance. They will also need to be able to solve engineering problems involving Ohm's law and the relationship between voltage, current and resistance, eg  $V = I R$ ,  $R = V/I$ , and  $I = V/R$ .

Learners will solve engineering problems involving series and parallel circuits (with up to four resistances) and combined series/parallel circuits (with up to four resistances and three branches). They will need to know about Kirchhoff's Voltage Law, Kirchhoff's Current Law and be able to solve engineering problems involving Kirchhoff's Laws and be able to determine the power in a DC circuit in terms of current, voltage and resistance, eg  $P = I V$ ,  $P = I^2 R$ ,  $P = V^2/R$ .

Learners will need to know about alternating current and how to solve engineering problems involving the voltage induced in a loop of wire rotating at constant velocity in a uniform magnetic field, eg  $e = B l v \sin \theta$ . They will need to know about sinusoidal voltage and current, definitions of amplitude (or peak value), peak-peak, rms and average values of a sinusoidal voltage taken over a half-cycle and the definitions and relationships between period (or periodic time). Learners will need to solve engineering problems involving angular velocity and frequency, eg  $f = 1/t$ ,  $t = 1/f$ ,  $\omega = 2\pi f$ , voltage and current in an AC circuit containing pure resistance, and be able to solve engineering problems involving power in an AC circuit in terms of current, voltage and resistance, eg  $P = I V$ ,  $P = I^2 R$ ,  $P = V^2/R$ . Learners will need to understand transformers and transformer principle (ideal or loss-free only considered), step-up and step-down types, and be able to solve engineering problems involving voltage and turns ratio, eg  $N_p/N_s = V_p/V_s = I_s/I_p$  and turns-per-volt.

**LO.4. Be able to apply the principles of heat and thermodynamics to determine the effects of expansion and compression of gases and energy transfer in engineering systems**

Learners will learn about heat energy and elementary molecular definition of solids, liquids and gases temperature, temperature scales, specific heat capacity, specific latent heat, linear and volumetric expansivity. They will need to solve engineering problems, eg gas laws, transfer of heat energy, change of state, expansion of solids and liquids.

Learners will need to understand expansion and compression of gases and polytropic processes, process parameters and relationships, eg absolute pressure, absolute temperature, volume, universal gas constant, molecular weight, characteristic gas constant, general gas equation ( $pV/T = \text{constant}$ ), characteristic gas equation ( $pV = mRT$ ), polytropic process equation ( $pV^n = \text{constant}$ ), value of  $n$  for isobaric processes ( $n = 0$ ), isothermal processes ( $n = 1$ ), adiabatic processes ( $n = \gamma$ ). Learners will need to solve engineering problems involving expansion and compression of gases, eg volume, pressure and temperature of a gas.

Learners will also learn about energy transfer in thermodynamic systems, closed thermodynamic systems, work transfer, eg general expression for a polytropic process, isothermal work transfer. They will cover heat transfer, eg specific heat capacities at constant volume and constant pressure, application of first law of thermodynamics, expression for change of internal energy, closed system energy equation, relationship between system constants  $c_v$ ,  $c_p$ ,  $\gamma$  and  $R$ . Learners will need to know about systems, eg internal combustion engine cylinders, positive pressure compressors; and will cover open thermodynamic systems, work transfer, eg general expression for a polytropic process, isothermal work transfer; heat transfer, eg application of first law of thermodynamics, expression for change of enthalpy, open system energy equation; systems, eg gas turbines, rotary compressors, coolers. Learners will also need to be able to solve engineering problems involving thermodynamic systems, eg energy and work output in a heat engine.

**LO.5 Know about the principles of chemistry and the effects of chemical processes and reactions**

Learners will need to understand chemical principles such as organic chemistry, chemical structure and bonding, chemical symbols and formulae, enthalpy change, definition of units, exothermic and endothermic reactions.

Learners will learn about reactions and industrial applications, alkanes (eg crude oil as the source of hydrocarbons), alkenes and aromatic compounds. They will cover the properties and behaviour of arenes (eg benzene) including combustion, treatment with bromine and acids, alkylation of benzene by the Friedel Crafts reaction. Learners will need to know about methods of producing industrial benzene, eg catalytic reforming, toluene hydrodealkylation, steam cracking. They will understand the uses of benzene in chemical manufacture, eg styrene (polymer and plastics production), phenol (resins and adhesives), cyclohexane (in the manufacture of nylon), rubbers, lubricants, dyes, detergents, drugs, explosives. Learners will be able to describe and explain industrial processes associated with petrochemicals.

Learners will also gain a knowledge of the properties and behaviour of phenols including combustion, solubility, treatment with sodium, aqueous sodium hydroxide, aqueous sodium carbonate. They will learn about ester formation, and be able to describe and explain industrial processes associated with phenols.

**LO.6 Be able to apply the principles of fluid dynamics to determine the effects of viscosity and the forces acting in hydrostatic systems**

Learners will need to know about the characteristics and behaviour of fluids, surface tension, capillary actions, viscosity and viscous behaviour, eg dynamic viscosity, kinematic viscosity, effect of shearing in Newtonian fluids (water, lubricating oils) and non-Newtonian fluids (pseudoplastic, Bingham plastic, Casson plastic, dilatent). Learners will also need to understand bearings, eg plain journal, plain thrust; system parameters, eg bearing dimensions, speed, viscosity of lubricant, power loss, and be able to solve engineering problems involving fluids.

Learners will need to know about forces in hydrostatic systems hydraulic devices, eg hydraulic jack, hydraulic press, hydraulic braking system, system parameters, eg cylinder dimensions, input and output forces, internal pressure, and be able to solve engineering problems involving hydrostatic systems.

Learners will need to know about immersed surfaces, eg retaining walls of tanks and reservoirs, lock and sluice gates, immersed rectangular and circular covers and hatches; system parameters, eg surface dimensions, depth of immersion, hydrostatic pressure and thrust, centre of pressure; and be able to solve engineering problems involving immersed surfaces.

Learners will need to understand principles of fluid flow, eg equation of continuity of mass, equation of continuity of volume for incompressible flow, Bernoulli's equation, D'Arcy's equation. Learners will learn about systems and devices, eg pipes of various sections and levels (such as an inclined tapering pipe); flow measurement, eg venturi meter, orifice meter, Pitot tube; aerodynamic profiles (eg spoilers, aircraft wings); and be able to describe and explain engineering applications of fluid flow.

## How you will be assessed

This unit will focus on your ability to apply scientific principles to the solution of practical engineering problems. Your tutor will set an assignment for you to complete which will comprise of different tasks and activities. These tasks will cover all of the scientific principles that you will have studied. At least some of these tasks will be set in a laboratory and they will provide you with an opportunity to carry out some practical 'hands on' engineering science investigations. Your tutor will provide you with the guidance necessary to complete each task.

You will receive a full briefing about the assignment and tasks well in advance of the date it is due for completion. This will allow you to carry out some preparatory background reading and research. You will be expected to complete the individual tasks under controlled conditions (usually during normal class teaching periods). All work must be completed by the end of the time allowed and handed to your tutor for marking. Your tutor will provide you with guidance on what is required and in what form it should be presented (note that assignments may often involve some practical laboratory work or an investigation of some item of hardware). You will often be required to illustrate your work with sketches, diagrams, charts and tables. Where problems have numerical solutions you will be required to show full working and state any assumptions made.

Task 1 covering assessment foci 1 and 2 could be based on activities involving coplanar forces and an investigation of Newton's laws of motion, or could be based on a scenario in which you solve a problem involving linear and angular motion.

Task 2 covering assessment focus 3 could be based on an investigation of a series/parallel circuit and electromagnetism.

Task 3 covering assessment foci 4 and 6 could be based on practical activities and problems based on energy transfer in a thermodynamic system and an investigation of the forces acting in hydrostatic systems.

The evidence you generate for these first three tasks will be submitted in separate 'process portfolios'.

Task 4 covering assessment focus 5 could be based on an investigation of a petrochemical process. The evidence should be submitted in a 'report'.

### Marking grid

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.1</b> <b>Be able to apply mechanical principles to determine the effects of forces in engineering systems</b>	Solves a system of two perpendicular coplanar forces and applies the principle of moments to a loaded system.  (0–4)	Solves a system of three non-perpendicular coplanar forces and determines the conditions for static equilibrium for a loaded beam.  (5–7)	Solves a system of four non-perpendicular coplanar forces, determines the conditions for static equilibrium for a loaded beam, and determines beam reactions due to loading.  (8–10)	10
<b>LO.2</b> <b>Be able to apply mechanical principles to determine the effects of motion, work and energy transfer in engineering systems</b>	Solves practical engineering problems involving linear motion and applies Newton’s laws of motion.  (0–4)	Solves practical engineering problems involving linear motion and angular motion, applies Newton’s laws of motion, and applies the principle of conservation of energy.  (5–7)	Solves practical engineering problems involving linear and angular motion and friction, applies Newton’s laws of motion, applies the principles of conservation of energy and conservation of momentum.  (8–10)	10

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<p><b>LO.3</b>  <b>Be able to apply electrical principles to determine the effects of electric charge and current and determine the voltage, current, resistance and power in electrical circuits</b></p>	<p>Solves practical engineering problems involving direct current circuits with a single source and load.</p> <p>(0–5)</p>	<p>Solves practical engineering problems involving direct current series/parallel-branches and applies basic principles of electromagnetism.</p> <p>(6–7)</p>	<p>Solves practical engineering problems involving direct current circuits with up to three series/parallel-branches, applies the principles of electromagnetism and electromagnetic coupling (ie a transformer connected between an AC source and a purely resistive load), and solves a practical engineering problem involving an AC circuit in which only pure resistance is present.</p> <p>(8–10)</p>	10
<p><b>LO.4</b>  <b>Be able to apply the principles of heat and thermodynamics to determine the effects of expansion and compression of gases and energy transfer in engineering systems</b></p>	<p>Solves practical engineering problems involving heat and thermodynamics.</p> <p>(0–4)</p>	<p>Solves practical engineering problems involving heat and applies thermodynamics to the expansion and compression of gases.</p> <p>(5–7)</p>	<p>Solves practical engineering problems involving heat, applies thermodynamics to the expansion and compression of gases, and applies the first law of thermodynamics.</p> <p>(8–10)</p>	10

Assessment focus	Mark Band 1	Mark Band 2	Mark Band 3	Maximum marks available
<b>LO.5</b> Know about the principles of chemistry and the effects of chemical processes and reactions	Describes the chemical composition, properties and industrial applications of arenes and phenols.  (0–4)	Describes and explains the chemical composition, properties, industrial applications, reactions and methods of producing arenes and phenols.  (5–7)	Describes and explains the chemical composition, properties, industrial applications, reactions, methods of production, and industrial processes associated with petrochemicals.  (8–10)	10
<b>LO.6</b> Be able to apply the principles of fluid dynamics to determine the effects of viscosity and the forces acting in hydrostatic systems	Solves practical engineering problems involving fluids at rest.  (0–4)	Solves practical engineering problems involving fluids at rest and in motion.  (5–7)	Solves practical engineering problems involving fluids at rest and in motion, and applies Bernoulli's and D'Arcy's equations.  (8–10)	10
<b>Total marks</b>			<b>60</b>	

## Assessment guidance

### Using the marking grid

- Each internally assessed unit has 60 available marks in total.
- In some units the marking grid has been split into two grids – A and B. Marking grid A contains all of the marking criteria for the unit except those which assess a learner's performance in practical activities which are recorded as a witness testimony or observation record. These make up grid B.
- Centres must ensure that learners undertake appropriate assessment tasks to enable them to achieve the requirements of each unit's marking grid(s).
- The basic principle is that this is a 'best fit' grid – ie the assessor must match the overall standard of work for an assessment focus to a band. It is NOT a hurdle approach, whereby the assessor cannot award marks from the next mark band if one item for an assessment focus from a lower mark band has been omitted, regardless of the quality of the rest of the work for that assessment focus.
- If a learner completes all they are asked to do in a band for an assessment focus, they can be awarded the full marks for that mark band.
- If a learner has clearly done more on one aspect of work for an assessment focus required by a mark band, the assessor should consider whether the learner can be awarded marks from the bottom of the next mark band.
- If a learner has completed less than required in any aspect of work for an assessment focus, or indeed omitted an aspect, then the mark moves down within the mark band.
- Marking is completely separate for each assessment focus – ie a learner can get mark band 3 on one assessment focus, mark band 1 on another etc, then all marks are added together for the unit total. It may be possible, depending on weighting of an assessment focus for a learner to pass a unit even if 0 has been given in marks for one assessment focus in the unit.
- A 0 mark should be used only where a learner provides no valid evidence. Any work that starts to address the requirements of the grid should normally be awarded at least one mark.
- Evidence generated for marking grid A will be moderated. This must be in the form of hard evidence which a moderator can reassess, such as learner produced written documents (eg short question answers, multiple choice question answers, materials from presentations, research notes), videos (dated) of practical activities or artefacts.
- Marks gained from marking grid A will be reported separately from those gained from marking grid B.

## Guidance for allocating marks

This section provides further guidance for the assessor on how to confirm marks within the objective approach. The guidance can be used to allocate specific marks for that band.

<b>Assessment focus LO.1</b>	
Mark Band 1–3 (0-10 marks)	<p>The learner solves a given system of two perpendicular coplanar forces in order to determine the magnitude (1 mark) and direction (1 mark) of the resultant force and is able to apply the principle of moments in order to determine the magnitude (1 mark) and position (1 mark) of a given force applied to a loaded beam when supported at a single point fulcrum in order to preserve equilibrium.</p> <p>Up to 3 marks can be awarded when the learner solves a given system of three non-perpendicular coplanar forces in order to determine the magnitude (1 mark) and direction (1 mark) of the resultant and is able to determine the conditions for static equilibrium for a given loaded beam (1 mark).</p> <p>Up to 3 marks can be awarded the learner solves a system of four non-perpendicular coplanar forces in order to determine the magnitude (1 mark) and position (1 mark) of the resultant and is able to determine beam reactions due to given loading (1 mark).</p>

<b>Assessment focus LO.2</b>	
Mark Band 1–3 (0-10 marks)	<p>The learner solves a practical engineering problem involving linear motion. For example, to determine the final linear velocity (1 mark) and distance travelled (1 mark) given the initial linear velocity, linear acceleration and time. The learner also solves a practical engineering problem involving the application of Newton's laws of motion. For example, to determine the force that must be applied to a given mass in order to produce a given acceleration (1 mark) and the consequent reaction force (1 mark).</p> <p>Up to 2 marks can be awarded when the learner solves a practical engineering problem involving angular motion. For example, to determine the final angular velocity (1 mark) and number of revolutions of a flywheel (1 mark) given the initial linear velocity, linear acceleration and time. The learner also solves a practical engineering problem involving the application of the principle of conservation of energy. For example, to determine the velocity of a given mass when it reaches the base of a frictionless ramp (1 mark).</p> <p>The learner solves a practical engineering problem involving friction. For example, to determine the friction force (1 mark) acting on a given mass on an inclined plane. Up to 2 marks can be awarded when the learner also solves a practical engineering problem involving the application of the principle of conservation of momentum. For example, the combined velocity (1 mark) and direction (1 mark) of a lorry and a car (of given masses, initial velocities and directions) after a collision between the two vehicles.</p>

<b>Assessment focus LO.3</b>	
Mark Band 1–3 (0-10 marks)	<p>Up to 5 marks can be awarded when the learner solves a practical engineering problem involving a direct current circuit. For example, the learner is able to determine the resistance of a circuit comprising three resistors connected in series-parallel (1 mark) and then uses Ohm's law to determine the current supplied (1 mark) and hence the total power dissipated (1 mark) and finally uses Kirchhoff's laws to determine the voltage dropped across each resistor (1 mark) and the current flowing in each resistor (1 mark).</p> <p>Up to 2 marks can be awarded when the learner solves a practical engineering problem involving magnetism. For example, the learner determines the force (1 mark) acting on a current carrying conductor given values of flux density, effective length and applied current. By using a labelled sketch and brief written explanation the learner shows how this effect can be used to from the basis of a simple electric motor (1 mark).</p> <p>Up to 3 marks can be awarded when the learner solves a practical engineering problem involving alternating current circuits and transformers. For example, the learner determines the e.m.f. induced (1 mark) across the ends of a conductor moving in a magnetic field at a given angle, flux density, and effective conductor length. By using a labelled sketch and brief written explanation the learner shows how this effect can be used to from the basis of a simple AC generator (1 mark). The learner determines the secondary voltage and power produced in a resistive load connected to a transformer when given values of primary voltage, turns ratio and secondary load resistance (the transformer assumed to be loss-free) (1 mark).</p>

<b>Assessment focus LO.4</b>	
Mark Band 1–3 (0-10 marks)	<p>Up to 2 marks can be awarded when the learner solves a practical engineering problem involving heat and thermodynamics. For example, the learner determines the energy required (1 mark) to convert a given mass of ice at 0°C to water at 0°C and then determines the heat energy to raise the mass to a given temperature (1 mark). Up to 2 marks can be awarded when the learner also calculates the change in length (1 mark) and volume (1 mark) of a metal bar of given coefficient of linear expansion and dimensions.</p> <p>Up to 2 marks can be awarded when the learner solves a practical engineering problem involving the expansion of a gas. For example, the learner determined the characteristic gas constant (1 mark) and specific heat capacity at constant pressure (1 mark) of a given mass and volume of gas at a given temperature. The learner also determines the volume of gas if the mass of gas is heated to a different temperature (1 mark).</p> <p>Up to 3 marks can be awarded when the learner solves a practical engineering problem involving energy transfer in a thermodynamic system. For example, the learner determines the magnitude (2 marks) and direction (1 mark) of the work done when a fluid enters and leaves a horizontal steady flow system with given enthalpies and kinetic energies.</p>

<b>Assessment focus LO.5</b>	
Mark Band 1–3 (0-10 marks)	<p>Up to 4 marks can be awarded when the learner describes the chemical composition, properties and industrial applications of arenes and phenols. For example, the learner describes the use of benzene in chemical manufacture with specific mention of styrene in the production of plastics (1 mark) and phenol in resins and adhesives (1 mark). The learner describes that arenes and phenols are based on benzene ring and the structure of benzene and phenol (1 mark) and their characteristic properties (1 mark).</p> <p>Up to 3 marks can be awarded when the learner explains a chemical reaction and method of producing an arene and phenol. For example, the learner explains the alkylation of benzene (1 mark) using the Friedel Crafts reaction (2 marks). For full marks at mark band 2 the learner explains the chemical reaction and method of producing a specific arene and phenol by referring to their chemical composition and properties, and showing how these have led to the resulting reaction and influenced the development of the relevant industrial process. The lower end of this mark band must still be characterised by answers that are explanatory rather than descriptive in nature.</p> <p>Up to 3 marks can be awarded when the learner describes and explains an industrial process associated with a petrochemical. For example, the learner uses an appropriate diagram (1 mark) and written explanation (1 mark) for catalytic reforming of industrial benzene (1 mark). For credit in mark band 3 the emphasis must be on industrial processing of petrochemicals. Responses that do not get this across clearly should be restricted to mark band 2.</p>

<b>Assessment focus LO.6</b>	
Mark Band 1–3 (0-10 marks)	<p>The learner solves a practical engineering problem involving static fluids. For example, the learner determines the pressure (2 marks) in a water pipe given the difference in height of the columns of fluid in a manometer tube, the density of the fluid in the tube, and the atmospheric pressure. The learner also determines the difference in height (2 marks) of the columns of fluid in the manometer tube when the atmospheric pressure is reduced by a given amount.</p> <p>Up to 3 marks can be awarded when the learner is able to solve a practical engineering problem involving immersed surfaces. For example, the learner determines the pressure (2 marks) and force (1 mark) acting on a flat plate of given surface area immersed at a given depth in fluid of given specific density.</p> <p>Up to 3 marks can be awarded when the learner is able to solve a practical engineering problem involving fluid dynamics. For example, the learner is able to determine the velocity (2 marks) and volume of water (1 mark) that will escape from a large open-top tank in a given time through an opening of given diameter and depth below the water level.</p>

## Approaches to assessment

Due to the diverse nature of the content, this unit will have to be assessed through a number of different individual tasks. These can typically involve learners carrying out experimental laboratory work, analysing data, and solving problems. It is recommended that tasks should include a significant proportion of ‘hands-on’ practical work as well as problem solving. Tasks should be carried out under controlled conditions and they should be time constrained. A typical task should be completed in under three hours.

Before carrying out a particular task, learners should be provided with a detailed verbal and written briefing together with an opportunity to ask questions. Safety aspects of work to be carried out by learners should be emphasised during the briefing session and any specific hazards should be identified. The initial briefing (which may be given to all learners in a group situation) should not be classed as ‘initial direction’ or ‘initial guidance’. The briefing should include:

- the title and purpose of the work or the detailed statement of a problem
- all required information (such as a table of material properties)
- the resources available to learners (and their location if not immediately accessible)
- the way that marks will be allocated
- the nature of the evidence that learners should present (eg tabulated data, graphs, calculations, diagrams, annotated photographs, etc)
- the time available for completion.

Learners should be reminded that they should complete the assessment without plagiarism and within the allocated time.

This unit clearly has several distinctive areas of study spread over 90 hours of guided learning which means that the assessment should be through the use of different tasks addressing all aspects of the unit. This means that the tasks can be spread over the duration of the delivery of the unit in a more even manner.

Task 1 could cover assessment foci 1 and 2. An activity for 1 could be based on work involving coplanar forces. For example, learners could be asked to carry out an analysis of the forces acting on the jib and supporting superstructure of a tower crane. They could be given photographs, scale drawings, and specifications and then be asked to use them to determine the forces in cables for maximum rated load, optimum counter-balance load, reaction on supporting tower, etc. Tutors should emphasise the link to Unit 3 for determining tensile load in cables.

A further practical activity covering assessment focus 2 might be based on an investigation of Newton’s laws of motion and the principles of conservation of momentum and energy, or on a scenario in which learners solve problems involving linear and angular motion (for example, a tracked vehicle moving up an inclined plane and the number of revolutions of a flywheel), conservation of energy (for example, involving a mass sliding down a frictionless ramp), and conservation of momentum (for example, involving a collision between two vehicles of given mass and velocity). Evidence for this task should be submitted in a ‘process portfolio’.

Task 2 covering assessment focus 3 could be based on a combination of practical activities and problem solving. Practical activities could involve the solution of a series-parallel network (checking measured results by applying Ohm’s law and Kirchhoff’s laws) and the investigation of a transformer-coupled AC circuit in which a low-voltage AC bench supply delivers power to a resistive load (checking measured result by applying relevant transformer equations). Problem solving could involve (a) determining the force on a current carrying conductor when moving at a constant velocity through a field of given flux density and (b) determining the emf generated

across the ends of a conductor when it moves through a field of given flux density. Learners could then be asked to explain (with the aid of appropriate sketches) how these two effects respectively underpin the principle of the DC motor and the AC generator. Evidence for this task should be submitted in a 'process portfolio'.

Task 3 could cover assessment focus 4 and 6. An activity for 4 could be based on a combination of practical work and problem solving based on energy transfer in thermodynamic systems. Learners could be asked to analyse the energy in a system when a given mass of ice is converted to water at a given temperature and the change in length that occurs when a metal bar of given dimension and coefficient of linear expansion is heated. Further activities could involve the determination of gas constant from data supplied when a given mass of gas is allowed to expand at given pressure and temperature and determination of the work done when a fluid enters and leaves a horizontal steady flow system with given enthalpies and kinetic energies.

The task for 6 could be based on static and dynamic systems involving fluids. Learners could be asked to measure the static pressure in a system using a simple manometer arrangement and then to check their results by calculation. They could also be asked to determine the pressure and force acting on a flat plate of given surface area immersed in a given depth of fluid of given density as well as determining the velocity and volume of water that would escape from an open-top tank in a given time from an opening of given diameter and depth below water level. In both cases, learners could be given photographs, sketches or scale drawings to work from. Evidence for this task should be submitted in a 'process portfolio'.

Task 4 covering assessment focus 5 could be based on an investigation of a petrochemical process involving, for example, production of industrial benzene. This could be based on a video or industrial visit and involve an explanation of the process and underlying chemical reactions.

Because this task is based on research and investigation carried out by the learner, evidence should be submitted in the form of a 'report'.

## Guidance for teaching this unit

### Delivery guidance

This unit is 90 guided learning hours (GLH) in length. Centres should allocate this amount of time within the timetable for its delivery and assessment. Edexcel has identified that within this time learners will probably require 30 GLH in activities which generate evidence for assessment. This may, for example, include time spent in experiential learning, practising skills, research activities and undertaking summative assessment activities. (See sections relating to *Internal assessment* and *Programme design and delivery* in the generic introductory part of the *Guidance and units* document.)

This unit provides the underpinning scientific knowledge that learners will need to fully understand much of the work covered in other Level 3 units.

There are significant links between the learning outcomes and centres should ensure that these links are emphasised. In particular, learners need to understand that many practical engineering systems involve mechanical and electrical components working together. Delivery strategies should be developed that will ensure that essential system concepts (such as power, energy and efficiency) are applicable in both mechanical and electrical contexts. Later, when investigating engineering systems as part of learning outcome 4, learners should be encouraged to look back at the work carried out previously in learning outcomes 1 and 2.

Learning outcomes 1 and 2 are likely to be delivered by formal lecture, discussion, demonstration and problem solving exercises (both on a class and individual learner basis). learning outcome 3 can be integrated into the delivery of the first two outcomes. Learners should be introduced to problem solving at the earliest possible stage. They should also be encouraged to make use of a variety problem solving techniques including the use of formulae, graphical and computer analysis. Learners should be encouraged to put into practice the mathematical concepts that they have learned from their study of Unit 4 (which could be taken concurrently with this unit). More complex problem solving can be introduced when learners have become familiar with the basic concepts and have had an opportunity to develop competence in the use of mathematics.

In relation to all four outcomes, every attempt should be made to enhance learning through use of appropriate laboratory work. The content of the outcomes has been designed to reflect the likely learning support time spent on them. It is envisaged that learning outcomes 1 and 2 will each require around 30% of the overall learning support time dedicated to the unit, leaving 20% to cover learning outcome 3 and 20% for learning outcome 4.

This unit has obvious analytical links with *Unit 8: Mathematical Techniques and Applications for Engineers* and both of these units should ideally be delivered concurrently. Regular and meaningful liaison between the tutors for these two units is essential. Opportunities for bringing mathematical theory to life should be sought on an ongoing basis.

### Guidance for the delivery of personal, learning and thinking skills (PLTS)

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
<b>Independent enquirers</b>	Identifying coursework questions and problems to resolve. Using and applying scientific concepts and principles to the solution of practical engineering problems (for example when determining the velocity and distance travelled by a vehicle). Assessment foci 1, 2, 3, 4 and 6.
<b>Creative thinkers</b>	Not present in this unit.
<b>Reflective learners</b>	Checking that answers to engineering problems are realistic and within an appropriate range. Assessment foci 1, 2, 3, 4, 5 and 6.
<b>Team workers</b>	Not present in this unit
<b>Self-managers</b>	Planning and organising the creation of their assignments for this unit. Dealing with time pressures and deadlines for the production of their assignments. Seeking advice and support from their peers and tutors when needed.
<b>Effective participators</b>	Using and applying scientific concepts and principles to the solution of practical engineering problems (for example when determining the velocity and distance travelled by a vehicle). Assessment foci 1, 2, 3, 4, 5 and 6.

## Functional skills – Level 2

This unit provides opportunities for the development of some of the functional skills in mathematics. In particular in making sense of situations and representing them, and processing and using mathematics, when they are solving engineering problems.

Learners will develop proficiency in using some basic scientific laboratory equipment (such as spring balances, micrometers, thermometers, ammeters and voltmeters). Learners will develop skills using a scientific calculator, including an ability to enter and manipulate data, when they are solving problems with numerical solutions. Learners will develop skills in presenting data in different forms when analysing experimental. Learners will develop proficiency in sketching diagrams and plotting graphs.

This unit also provides opportunities for the development of some of the functional skills in English when carrying out library research into underpinning scientific principles (for example, Lenz's Law, Bernoulli's Theorem, the Friedel Crafts reaction, etc) and when describing industrial applications (such as the production and petrochemicals).

### Work experience

In order to emphasise the practical application of science in an engineering context it can be extremely advantageous to use a programme of relevant practical investigations to reinforce the underlying scientific principles. This will require access to an appropriately equipped engineering science laboratory or to individual laboratories specifically equipped for the teaching of mechanical and electrical science.

For the delivery of learning outcomes 1 and 2 the equipment (normally found in a science or mechanics laboratory) can be used. This includes apparatus such as simple force boards, spring/mass systems, tensile test machines such as the Hounsfield tensometer, Fletcher's trolley, friction equipment, and apparatus needed to determine momentum of bodies and circular motion parameters. Learners will also require access to mechanical measuring and test equipment, such as balances, stop clocks, etc.

For the electrical outcomes (3 and 4), learner access to equipment such as simple circuit boards, electrostatic and magnetic equipment and basic electrical would assist learning. Learners will also require access to electrical measuring and test equipment, such as power supplies, multimeters and oscilloscopes.

Learners will also require access to relevant scientific data and internet resources. Access to a PC with spreadsheet and graph/chart plotting software would also be advantageous for analysing and presenting data.

### Reference material

Bird J – *Science for Engineering* (Newnes, 2003) ISBN 0750657774

Bolton W – *Engineering Science, Fourth Edition* (Newnes, 2001) ISBN 0750652594

Darbyshire A and Bolton W – *Mechanical Engineering: BTEC National option units, First Edition* (Newnes, 2004) ISBN 0750657618

Tooley M and Dingle L – *BTEC National Engineering, Second Edition* (Newnes, 2007) ISBN 0750685212



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## Annexe A: Qualification codes

The National Qualifications Framework (NQF) code is known as a Qualification Accreditation Number (QAN). This is the code that features in the DfES Funding Schedules – Sections 96 and 97 and is to be used for all qualification funding purposes. Each unit within a qualification will also have an NQF unit code.

The qualification and unit codes will appear on the learner’s final certification documentation.

The QANs for the qualifications in this publication are:

500/2359/7 Edexcel Level 3 Principal Learning in Engineering

These Principal Learning qualifications contribute to the following Diploma qualifications at the same level:

500/2808/X Edexcel Level 3 Advanced Diploma in Engineering

500/2804/2 Edexcel Level 3 Progression Diploma in Engineering

These qualification titles will appear on learners’ certificates.

Learners need to be made aware of this when they are recruited by the centre and registered with Edexcel. Providing this happens, centres are able to describe the programme of study leading to the award of the qualification in different ways to suit the medium and the target audience.

### Other codes

The codes below will be required when making entries for individual units and the overall Principal Learning qualification:

Unit codes	Each unit is assigned a unit code. This unit code is used as an entry code to indicate that a learner wishes to take the assessment for that unit. Centres will need to use the entry codes only when entering learners for their examination or coursework moderation.	Please refer to the Edexcel <i>Information Manual</i> , available on the Edexcel website.
Cash-in codes	The cash-in code is used as an entry code to aggregate the learner’s unit scores to obtain the overall grade for the qualification. Centres will need to use the cash-in codes only when entering learners for their qualification award.	Please refer to the Edexcel <i>Information Manual</i> , available on the Edexcel website.



# Annexe B: Personal, learning and thinking skills

## QCA – a framework of PLTS

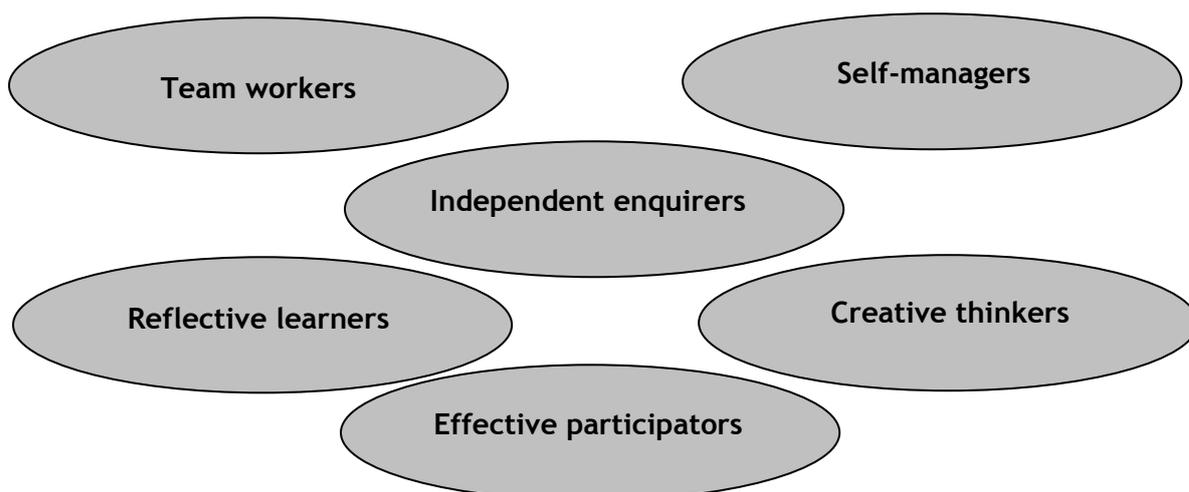


Qualifications and  
Curriculum Authority

### A FRAMEWORK OF PERSONAL, LEARNING AND THINKING SKILLS 11-19 IN ENGLAND

The framework comprises six groups of skills that, together with the functional skills of English, mathematics and ICT, are essential to success in learning, life and work. In essence the framework captures the essential skills of: managing self; managing relationships with others; and managing own learning, performance and work. It is these skills that will enable young people to enter work and adult life confident and capable.

The titles of the six groups of skills are set out below.



For each group there is a focus statement that sums up the range of skills. This is followed by a set of outcome statements that are indicative of the skills, behaviours and personal qualities associated with each group.

Each group is distinctive and coherent. The groups are also inter-connected. Young people are likely to encounter skills from several groups in any one learning experience. For example an Independent enquirer would set goals for their research with clear success criteria (Reflective learner) and organise and manage their time and resources effectively to achieve these (Self-manager). In order to acquire and develop fundamental concepts such as organising oneself, managing change, taking responsibility and perseverance, learners will need to apply skills from all six groups in a wide range of learning contexts 11–19.

## The Skills

### Independent enquirers

*Focus:*

Young people process and evaluate information in their investigations, planning what to do and how to go about it. They take informed and well-reasoned decisions, recognising that others have different beliefs and attitudes.

Young people:

- identify questions to answer and problems to resolve
- plan and carry out research, appreciating the consequences of decisions
- explore issues, events or problems from different perspectives
- analyse and evaluate information, judging its relevance and value
- consider the influence of circumstances, beliefs and feelings on decisions and events
- support conclusions, using reasoned arguments and evidence

### Creative thinkers

*Focus:*

Young people think creatively by generating and exploring ideas, making original connections. They try different ways to tackle a problem, working with others to find imaginative solutions and outcomes that are of value.

Young people:

- generate ideas and explore possibilities
- ask questions to extend their thinking
- connect their own and others' ideas and experiences in inventive ways
- question their own and others' assumptions
- try out alternatives or new solutions and follow ideas through
- adapt ideas as circumstances change

### Reflective learners

*Focus:*

Young people evaluate their strengths and limitations, setting themselves realistic goals with criteria for success. They monitor their own performance and progress, inviting feedback from others and making changes to further their learning.

Young people:

- assess themselves and others, identifying opportunities and achievements
- set goals with success criteria for their development and work
- review progress, acting on the outcomes
- invite feedback and deal positively with praise, setbacks and criticism
- evaluate experiences and learning to inform future progress
- communicate their learning in relevant ways for different audiences

### Team workers

*Focus:*

Young people work confidently with others, adapting to different contexts and taking responsibility for their own part. They listen to and take account of different views. They form collaborative relationships, resolving issues to reach agreed outcomes.

Young people:

- collaborate with others to work towards common goals
- reach agreements, managing discussions to achieve results
- adapt behaviour to suit different roles and situations
- show fairness and consideration to others
- take responsibility, showing confidence in themselves and their contribution
- provide constructive support and feedback to others

### Self-managers

*Focus:*

Young people organise themselves, showing personal responsibility, initiative, creativity and enterprise with a commitment to learning and self-improvement. They actively embrace change, responding positively to new priorities, coping with challenges and looking for opportunities.

Young people:

- seek out challenges or new responsibilities and show flexibility when priorities change
- work towards goals, showing initiative, commitment and perseverance
- organise time and resources, prioritising actions
- anticipate, take and manage risks
- deal with competing pressures, including personal and work-related demands
- respond positively to change, seeking advice and support when needed

### Effective participators

*Focus:*

Young people actively engage with issues that affect them and those around them. They play a full part in the life of their school, college, workplace or wider community by taking responsible action to bring improvements for others as well as themselves.

Young people:

- discuss issues of concern, seeking resolution where needed
- present a persuasive case for action
- propose practical ways forward, breaking these down into manageable steps
- identify improvements that would benefit others as well as themselves
- try to influence others, negotiating and balancing diverse views to reach workable solutions
- act as an advocate for views and beliefs that may differ from their own

(See [www.qca.org.uk/qca\\_16953.aspx](http://www.qca.org.uk/qca_16953.aspx))

## PLTS Performance Indicator (suggested recording sheet)

Name:	Date:				
	Level of success 1 = low, 5 = high				
<b>Independent enquirers</b>					
Identify questions to answer and problems to resolve	1	2	3	4	5
Plan and carry out research, appreciating the consequences of decisions	1	2	3	4	5
Explore issues, events or problems from different perspectives	1	2	3	4	5
Analyse and evaluate information, judging its relevance and value	1	2	3	4	5
Consider the influence of circumstances, beliefs and feelings on decisions and events	1	2	3	4	5
Support conclusions, using reasoned arguments and evidence	1	2	3	4	5
<b>Creative thinkers</b>					
Generate ideas and explore possibilities	1	2	3	4	5
Ask questions to extend their thinking	1	2	3	4	5
Connect their own and others' ideas and experiences in inventive ways	1	2	3	4	5
Question their own and others' assumptions	1	2	3	4	5
Try out alternatives or new solutions and follow ideas through	1	2	3	4	5
Adapt ideas as circumstances change	1	2	3	4	5
<b>Reflective learners</b>					
Assess themselves and others, identifying opportunities and achievements	1	2	3	4	5
Set goals with success criteria for their development and work	1	2	3	4	5
Review progress, acting on the outcomes	1	2	3	4	5
Invite feedback and deal positively with praise, setbacks and criticism	1	2	3	4	5
Evaluate experiences and learning to inform future progress	1	2	3	4	5
Communicate their learning in relevant ways for different audiences	1	2	3	4	5
<b>Team workers</b>					
Collaborate with others to work towards common goals	1	2	3	4	5
Reach agreements, managing discussions to achieve results	1	2	3	4	5
Adapt behaviour to suit different roles and situations	1	2	3	4	5
Show fairness and consideration to others	1	2	3	4	5
Take responsibility, showing confidence in themselves and their contribution	1	2	3	4	5
Provide constructive support and feedback to others	1	2	3	4	5
<b>Self-managers</b>					
Seek out challenges or new responsibilities and show flexibility when priorities change	1	2	3	4	5
Work towards goals, showing initiative, commitment and perseverance	1	2	3	4	5
Organise time and resources, prioritising actions	1	2	3	4	5
Anticipate, take and manage risks	1	2	3	4	5
Deal with competing pressures, including personal and work-related demands	1	2	3	4	5
Respond positively to change, seeking advice and support when needed	1	2	3	4	5
<b>Effective participators</b>					
Discuss issues of concern, seeking resolution where needed	1	2	3	4	5
Present a persuasive case for action	1	2	3	4	5
Propose practical ways forward, breaking these down into manageable steps	1	2	3	4	5
Identify improvements that would benefit others as well as themselves	1	2	3	4	5
Try to influence others, negotiating and balancing diverse views to reach workable solutions	1	2	3	4	5
Act as an advocate for views and beliefs that may differ from their own	1	2	3	4	5

**Note to learner:** The circled number represents an indication of your PLTS performance so far.

**Note to tutor:** Indicate the level of success by circling the appropriate number during your feedback with the learner.

## Summary of the PLTS coverage throughout the programme

### Level 3

Personal, learning and thinking skill	Unit								
	1	2	3	4	5	6	7	8	9
Independent enquirers	X	✓	✓	X	X	✓	✓	X	✓
Creative thinkers	X	✓	X	X		X	✓	X	
Reflective learners	X	X	X	X	✓	X	X	X	X
Team workers						✓			
Self-managers	X	X	✓	X	✓	✓	X		X
Effective participators		X	X		✓	✓	X	X	X
✓ – required component X – opportunities for development									



# Annexe C: Wider curriculum mapping

Study of the Edexcel Diplomas in Engineering provides opportunities for the learner to develop an understanding of spiritual, moral, ethical, social and cultural issues as well as an awareness of citizenship, environmental issues, European developments, health and safety considerations and equal opportunities issues.

The Edexcel Diplomas in Engineering make a positive contribution to wider curricular areas as appropriate.

## **Spiritual, moral, ethical, social and cultural issues**

The specification contributes to an understanding of moral, ethical, social and cultural issues, especially when learners are dealing with colleagues and customers.

## **Citizenship issues**

Learners undertaking the Principal Learning in Engineering will have the opportunity to develop their understanding of citizenship issues throughout the Edexcel Diplomas in Engineering.

## **Environmental issues**

Learners are led to appreciate the importance of environmental issues throughout the engineering sector. Many of the units allow learners to consider the influence that engineering processes have on the environment and the ways that this impact can be reduced.

## **European developments**

Much of the content of the Edexcel Diplomas in Engineering applies throughout Europe even though the delivery is in a UK context.

## **Health and safety considerations**

The Edexcel Diplomas in Engineering are practically based and so health and safety issues are encountered throughout the units. Learners will develop awareness of the safety of others as well as themselves in all practical activities.

## **Equal opportunities issues**

Equal opportunities issues are implicit throughout the Edexcel Diplomas in Engineering.

## Wider curriculum mapping

### Level 3

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9
Spiritual									
Moral and ethical	✓								
Social and cultural	✓						✓		
Citizenship issues	✓						✓		
Environmental issues	✓	✓	✓	✓	✓	✓	✓		
European developments	✓	✓	✓	✓	✓	✓	✓		
Health and safety considerations	✓		✓	✓	✓	✓	✓		
Equal opportunities issues	✓	✓	✓	✓	✓	✓	✓	✓	✓

## Annexe D: Glossary of terms

There are some terms that you may come across in the specification, which have a particular meaning within the context of the Diploma. **You are therefore advised to familiarise yourself with the definitions of the terms in this glossary.**

Term	Definition
Additional learning	Units or qualifications that learners choose to include in their Diploma. Additional learning is complementary in character. It consists of further learning and can include national curriculum entitlement areas and/or learning options such as languages, music or science that relate to individual needs, interests and aspirations, provided these do not duplicate learning in Principal Learning and Generic Learning.
Applied learning	Acquiring and applying, knowledge, skills and understanding through <i>tasks</i> set in sector <i>contexts</i> that have many of the characteristics of real work or are set within the workplace. Most importantly, the <i>purpose</i> of the task in which learners apply their knowledge, skills and understanding must be relevant to real work in the sector.
Assessment criteria	Specify the standard a learner is expected to meet to demonstrate that a learning outcome, or set of learning outcomes, has been achieved. Assessment criteria should be sufficiently detailed to support a consistent judgement that a learning outcome has been achieved – there are no minimum or maximum number of assessment criteria that relate to each learning outcome. The criteria should not dictate the method of assessment to be used.
Diploma	A defined set of qualifications that have been combined according to a set of rules. The Diplomas are designed to support progression to further study, training and employment.
Experiential learning	A process that stresses the central role of experience in learning related to the world of work. Learners reflect on their experience, draw out and articulate lessons learnt (generalise), and then apply their learning to new situations or activities.
External assessment	Assessment tasks are set and candidates' work is assessed by Edexcel.
Formative assessment	This is concerned with the short-term collection and use of evidence as guidance of learning, mainly in day-to-day classroom practice.
Functional skills	Functional skills are core elements of English, mathematics and ICT, providing the essential knowledge, skills and understanding needed to operate confidently, effectively and independently in life and at work.

Term	Definition
Generic Learning	<p>Generic Learning enables learners to develop and apply the skills and knowledge necessary for learning, employment and personal development.</p> <p>The Generic Learning component of the Diploma is made up of the following constituent parts:</p> <ul style="list-style-type: none"> <li>• functional skills</li> <li>• personal, learning and thinking skills</li> <li>• a project</li> <li>• work experience.</li> </ul>
Generic skills	<p>Generic skills are relevant to learning, training and working in all lines of learning and all sectors. They include functional skills and personal, learning and thinking skills.</p>
Internal assessment	<p>Tasks are set and marked against criteria provided by Edexcel and subjected to external moderation. Internal assessment is normally supervised and conducted under controlled conditions.</p>
Level	<p>The level at which a qualification or unit is positioned for accreditation. Levels are defined in terms of complexity, autonomy and range of achievement.</p>
Line of learning	<p>The broad subject areas that each Diploma will cover. There are 17 lines of learning, including: Creative and Media; Information Technology; Society, Health and Development; Engineering; Construction and the Built Environment.</p>
Personal, learning and thinking skills (PLTS)	<p>The framework of skills, which will equip all young people for successful employment and lifelong learning. PLTS require learners to be:</p> <ul style="list-style-type: none"> <li>• independent enquirers</li> <li>• creative thinkers</li> <li>• reflective learners</li> <li>• team workers</li> <li>• self-managers</li> <li>• effective participators.</li> </ul>
Principal Learning	<p>Learning modules and units of assessment that the learner must include in their Diploma. Principal Learning includes a minimum of 50 per cent of applied learning and consists of knowledge, understanding, skills and attitudes that support progress through the line of learning into the sectors concerned. Opportunities to develop and apply generic skills are also integrated into Principal Learning.</p>
Project	<p>A freestanding qualification within the Diploma.</p>

Term	Definition
Specialist learning	Units or qualifications that learners choose to include in their Diploma. Specialist learning allows the learner to take up further, more specialist learning, within their line of learning. It consists of qualifications and units that will support progression across the range of progression pathways within a chosen sector, as identified and recommended by the employers and higher education advisers on the Diploma Development Partnership.
Summative assessment	This serves to inform an overall judgement of achievement.
Transcript	A report of the units and qualifications that make up a learner's programme and achievement. It lists the learner's units and grades for each of the components of their Diploma qualification and also records work experience and personal, learning and thinking skills.
Work experience	A component of the Diploma, which enables learners to utilise and develop their knowledge and skills in the actual workplace.



# Annexe E: Internal Assessment of Principal Learning Units: Controls for Task Setting, Task Taking and Task Marking – for Principal Learning in Construction and the Built Environment, Creative and Media, Engineering, Information Technology and Society, Health and Development

This annexe should be read in association with the latest edition of the Joint Council for Qualifications document ‘GCSE, GCE, ELC, Functional Skills, Principal Learning in the Diploma and Project Qualifications – Instructions for conducting coursework’, available from the JCQ website, [www.jcq.org.uk](http://www.jcq.org.uk)

## Section 1: Introduction

It is a requirement of the *Criteria for accreditation of Diploma qualifications at Levels 1, 2 and 3* that:

‘Internal assessment [of Principal Learning] must normally be supervised and conducted under controlled conditions to ensure reliability and fairness.’

Further guidance from the Qualifications and Curriculum Development Agency has identified three stages of assessment for which control must be specified:

- **Task setting**
- **Task taking** (controls on time, resources, supervision, and collaboration)
- **Task marking.**

Further to the areas specified above, this annexe in collaboration with the individual specifications also sets the parameters for:

- guidance and support;
- submission, revision, re-working;
- the involvement of parents/carers;
- malpractice; and the authentication of learners’ work.

This annexe details the controls that normally apply to all Edexcel Principal Learning internally assessed units. However tutors and assessors must also apply any specific controls or additional requirements that may be identified within the *Assessment information for assessors* section in individual units.

There are three levels of control that can apply to each stage.

<b>High control</b>	Where the assessment requirements are tightly prescribed.
<b>Medium control</b>	Where the assessment requirements are specified in terms of parameters that allow consortia some flexibility to suit local circumstances.
<b>Limited control</b>	Where the assessment requirements are specified in terms of broad parameters that allow consortia to determine the details of the assessment.

It is the responsibility of the consortium to ensure that internal controlled assessment for Principal Learning is conducted and marked in accordance with the requirements specified by Edexcel and conducted in line with the *JCQ Instructions for conducting coursework*.

## Section 2: Edexcel Controlled Assessment Profile

In Edexcel's internally-assessed Principal Learning units, some aspects are subject to medium control and others have limited control. The table below shows the standard profile for all Edexcel Principal Learning internally-assessed unit specifications. Individual unit specifications will indicate where a divergence has occurred from this profile.

Aspect	Level 1	Level 2	Level 3
Task setting	Limited	Limited	Limited
Time	Limited	Limited	Limited
Resources	Limited	Limited	Limited
Supervision	Medium	Medium	Medium
Collaboration	Limited	Limited	Limited
Marking	Medium	Medium	Medium

## Section 3: Assessment controls

### 3.1 Task setting

#### Limited control

Edexcel will publish, as part of its tutor support materials, at least one model assignment for each internally assessed unit. It is recommended that these model assignments are used in the assessment of each unit. However in order that these assignments can best meet learner interests and local needs they will include guidance for tutors and assessors to show the ways in which they may be adapted and contextualised. If the tutor decides to either adapt or write their own assignments then each assignment must meet the following conditions:

- each internally assessed unit must be assessed through a single coherent assignment which addresses the overall theme of the unit to emphasise how the different learning outcomes all relate to each other. Each assignment may be broken down into a series of related tasks
- assignments must have an applied work-related context
- across all tasks, assignments must address all learning outcomes and assessment criteria, and must give access to the full range of marks
- the evidence produced must conform to the requirements published in the *How you will be Assessed* section of the relevant unit specification
- in some units the marking grid is divided into parts A and B. All tasks which will be marked against the A grid must generate learner evidence that can be re-assessed at a later stage during internal standardisation activity or external moderation

- where tutors decide to set their own assignments, another person, who understands the requirements of the specification, **must** check that each new assignment is appropriate for the line of learning and the level, and also that a new assignment will allow candidates full access to the marking criteria. This is especially important when a new tutor/assessor is required to produce assignments. Suitable people may include a Domain or Lead Assessor. This review process must be documented and the evidence of the review must be made available for the external moderator if requested
- if the assignment is to be produced outside the teaching institution, for example by a supervisor at the learner's work experience placement, then the tutor or assessor at the teaching institution responsible for that unit, must sign off the assignment for validity before the learner attempts the assignment.

In addition to these requirements, further guidance on writing assignments is provided in this specification, in the section 'Assessment and grading of the principal learning specifications'.

### *Complexity*

If the level of complexity of the evidence required is not already identified within the specification, then an indication can be assumed from the amount of time set within the specification for the production of the assessment evidence, considering the level at which the specification is being taken. The expectations of what a Level 1 learner can accomplish in 10 hours are far different from that which can be expected from a Level 3 learner in the same time period.

Unless it is otherwise specified, learners should be set a task of equivalent complexity, whether they are expected to achieve marks at mark band 1 of the marking grid or mark band 3.

## **3.2 Task taking (controls on time, resources, supervision, and collaboration)**

If not specified within the unit, it is to be assumed that tasks or the whole assignment will normally be attempted at the end of the learning process.

### **Time – Limited control**

Each unit has a time for assessment allocated. While it is not a requirement that this time should be observed to the minute for internal assessments, it should be taken as strong guidance and variance should not normally be by more than plus or minus 10%. Learners given significantly less time may well be disadvantaged in relation to the quality and breadth of work they can produce, while those given significantly more may well be disadvantaged by an excess of time spent on assessment rather than learning.

### **Resources – Limited control**

Unless otherwise stated in the individual unit specification, learners are entitled to have full access to all resources seen fit for purpose by the centre tutor/assessor. Any specific resources (eg equipment, published material) required or prohibited for assessment will be detailed in the individual unit.

### **Supervision – Medium control**

Learners must normally be supervised by the centre tutor/assessor whilst producing evidence for the summative assessment activity, unless otherwise stated in the individual unit specification. Supervision is defined as normal classroom/workshop/studio working conditions, with the tutor/assessor being present in the same room whilst the summative assessment evidence is produced by the learner, but not requiring examination conditions.

Where supervision is relaxed:

- because it is not possible to directly supervise the activity that is required to produce summative assessment evidence, eg researching data, then the tutor/assessor must authenticate the learner work following the process identified in the section headed ‘Authentication’; or
- because the most suitable environment for producing the evidence means the tutor/assessor cannot be present, eg work experience, the tutor/assessor must ensure an appropriate person supervises the evidence production. All such evidence must be authenticated (see *Authentication* below) and, where this covers performance evidence, a signed learner observation record must be completed with enough reliable information to allow the tutor to accurately assess the evidence (see *3.4 Task marking* below).

It is not permissible for summative assessment evidence to be produced in the learner’s home environment, without the direct supervision of their assessor.

Due to the nature of producing an artefact, its production as part of the summative assessment will often be dictated by the availability of materials, equipment etc, therefore it may well be produced outside of the centre. However, the assessor must be confident that the work is that of the learner. In order to be confident, Edexcel requires one of the following situations to apply:

- the work is carried out under the direct supervision of the teaching centre assessor. This is the most desirable option
- the learner demonstrates to the teaching centre assessor equivalent levels of skill in each of the processes included in the production of the final artefact. Ideally this would be in the course of the regular teaching/learning programme, but exceptionally, if the assessor feels a skill has been assessed at a level beyond expectations, the assessor may require the learner to repeat that skill before authenticating the work.

If the artefact can only be produced remotely, for example during work experience, the assessor must have enough reliable information to allow them to both accurately assess the outcome and have a signed learner observation record from an appropriate person who directly observed the learner producing the artefact. An ‘appropriate person’ is defined as someone with a supervisory role within the workplace (or equivalent), and who has the required skills. This person must not be a family member, and must record and supply the required information for the assessor.

### **Collaboration (Group work) – Limited control**

Some units may require learners to work as part of a group. In other units, unless it is specifically forbidden, tutors may choose to have learners working collaboratively. When producing assignments which require or allow learners to work in groups, tasks must be written to allow each group member to fully meet the requirements of the assessment criteria.

Learners must not have their assessment opportunities reduced by the poor performance of other group members. Where this becomes apparent the tutor or assessor should intervene, or provide suitable alternative activities which do not greatly add to the learners’ workloads.

Group tasks should not rely on the performance of individual members of the group to allow other group members to meet all of the assessment criteria.

It is important that each learner is assessed on their individual contribution to the achievements of the group. Where several individuals contribute to a single piece of work, individual contributions must be clearly shown on the work to enable external moderation to take place. This can be indicated by learners or through the tutor’s annotations.

## Guidance and support

At the start of the assignment learners will often be required to plan out their programme of work. The tutor/assessors should agree these plans and where appropriate agree milestones where they can monitor learners' responses. Appropriate intervention is to be encouraged to ensure learners have every opportunity of success. However, if the planning process forms part of the assessment criteria, care must be taken to ensure that the plan remains the learner's own work.

Within some unit specifications, the level of assistance given to a learner is a discriminating factor used to decide a learner's positioning within the marking bands. To aid the assessor in selecting the appropriate level of assistance given to the learner a glossary of descriptors is included in the units and should be used for guidance when marking the learners work. In some cases, where a glossary doesn't exist, the following definitions should be used:

- *Assistance* – The learner has to be guided and advised to make progress, and responds to ideas suggested. The tutor/assessor needs to direct significant aspects of the work.
- *Limited assistance* – The learner suggests ideas for themselves, but makes use of guidance and advice from the tutor/assessor to make progress. The tutor/assessor assists in some aspects of the work, but generally does not direct it.
- *Independently* – The learner develops ideas themselves, using the tutor/assessor as an advisor rather than as a director. The tutor/assessor facilitates the work but does not need to direct its progress.

It is expected that all learners should develop as independent learners, but this does not mean that they should not be given any support in order to be able to research, write up and complete their reports. The hallmark of the independent learner, whatever the level, is knowing when and whom to ask for support in helping to carry the work forward.

All learners must be fully and equally briefed at the start of any task or assignment about the requirements of that task, including how they will be marked. They should be given the opportunity to ask any questions in order to clarify the requirements.

Once the assignment is under way, the tutor should respond to questions and requests for advice, but should normally refrain from intervening unasked. Responses can advise the learner on such matters as further sources of information, and can point out where further work is needed, but must always stop short of actually stating what to write.

In some units the amount of support and guidance a learner may receive in the course of carrying out the task or assignment is specified. This occurs, for example, when differentiation between mark bands is achieved in part by the support the learner needs to complete a practical task safely.

Tutors or assessors must always intervene where matters of health and safety are concerned. When this happens, the assessor should make a judgement about the appropriate marks that can be applied to the learner's work in the light of the intervention, and attach to the work a record of the intervention and justification for the marks awarded.

### 3.3 Feedback, re-working and submission

*All Principal Learning awarding bodies are required to follow the instructions for feedback, re-working and submission specified by the JCQ*

Candidates are free to **revise and redraft** a piece of coursework without teacher involvement before submitting the final piece. Candidates should be advised to spend an appropriate amount of time on the work commensurate with the marks available.

Teachers may review coursework before it is handed in for final assessment. Provided that advice remains at the general level, enabling the candidate to take the initiative in making amendments, there is no need to record this advice as assistance or to deduct marks. Generally one review should be sufficient to enable candidates to understand the demands of the assessment criteria. Advice may be given in either oral or written form.

Having reviewed the candidate's coursework **it is not acceptable** for teachers to give, either to individual candidates or to groups, detailed advice and suggestions as to how the work may be improved in order to meet the assessment criteria. Examples of unacceptable assistance include:

- detailed indication of errors or omissions
- advice on specific improvements needed to meet the criteria
- the provision of outlines, paragraph or section headings, or writing frames specific to the coursework task(s)
- personal intervention to improve the presentation or content of the coursework.

As indicated above, a clear distinction must be drawn between any interim review of coursework and final assessment for the intended examination series. Once work is submitted for final assessment it may not be revised: in no circumstances are 'fair copies' of marked work allowed. **Adding or removing any material to or from coursework after it has been presented by a candidate for final assessment will constitute malpractice.**

Where coursework is submitted in digital format there may be instances where the construction of the e-coursework does not attract any marks, in which case this construction may be done by the teacher instead of the candidate.

If a candidate requires additional assistance in order to demonstrate aspects of the assessment, the teacher should award a mark which represents the candidate's unaided achievement. The authentication statement should be signed and information given on the Candidate Record Sheet.

Teachers must keep live coursework secure and confidential at all times whilst in their possession. It is not acceptable for teaching staff to share coursework with other candidates.

There may be occasions when a learner needs to retake a task or assignment. This is acceptable at the discretion of the tutor, but the assignment should normally be set in a different context so that the learner is not repeating exactly the same tasks which they have had the chance to practise beforehand. Individual units will have further guidance where appropriate.

### **Authentication**

All candidates must confirm that any work they submit for assessment is their own.

Where learners are required to gather information and resources, tutors or assessors should take the opportunity to discuss authentication and plagiarism at the outset.

Where learner observation records and practical activity logs are required Edexcel will provide exemplar pro formas. Centres may choose to develop their own documentation, but they must record at least the information contained within the exemplar pro formas.

Once the assignment has been completed the assessor may need to interview or test the learner on their understanding of the information and/or the resources that they have identified and used. This may be necessary if, for example:

- the assessor needs to confirm the authenticity of the work
- the unit marking grid carries marks for information and/or resource gathering.

It will be up to the centre assessor to decide on the appropriate format, although the activity should be of a 'closed book' nature.

If the assessor decides to interview the learner, the assessor is required to question the learner regarding their information or resources until the assessor is sufficiently satisfied with the authentication. Whilst the interview is in progress the learner should not have access to the information or resources unless the individual unit specifies otherwise. It can be either a group or individual interview.

If the assessor decides to test the learner, the assessor is required to follow the usual testing format, with learners working in silence, and placed in a manner so that they do not see other learners' responses. The questions are at the discretion of the assessor, as is the length and timing of the test. Learners are not permitted to view the questions prior to the test and should not have access to their work during the test unless the individual unit specifies otherwise.

The documented outcome could be either notes following an interview with one or a group of learners and signed by the assessor, or marked test papers.

Each candidate is required to sign a declaration before submitting their coursework to their subject tutors/assessors for final assessment, to confirm that the work is their own and that any assistance given and/or sources used have been acknowledged. Ensuring that they do so is the responsibility of the candidate's centre.

It is also a requirement that tutors/assessors confirm to the awarding body that all of the work submitted for assessment was completed under the required conditions and that they are satisfied that the work is solely that of the individual candidate concerned. Where assessment is supervised by someone other than the tutor, additional confirmation is required from the person who has supervised the assessment.

All tutors/assessors who have assessed the work of any candidate entered for each component must sign the declaration of authentication.

### **3.4 Task marking (standardisation and marking) - Medium control**

#### **Marking**

Edexcel requires all consortium assessors to use only Edexcel authorized documentation in the assessment of its Principal Learning internal assessed units. All Edexcel Principal Learning internal assessed unit specifications have mark descriptors, and these must be used when assessing learner work. Consortium assessors must not try to re-interpret the mark descriptors, or use any other unauthorised publication which aims to do so.

If written evidence and artefacts are completed under the supervision of someone else (see *Supervision* above), this person may comment upon what is produced, but only the tutor can allocate marks.

Where performance evidence is observed by someone other than the tutor, this person must record their comments on the learner observation record. It is then the responsibility of the tutor to judge this evidence and allocate marks.

#### **Standardisation**

*All Principal Learning awarding bodies are required to follow the instructions for standardisation specified by the JCQ.*

Centres should use reference and archive materials (such as exemplar material provided by the awarding body or, where available, work in the centre from the previous year) to help set the standard of marking within the centre.

Prior to marking, a trial marking exercise should be undertaken. Teachers mark the same relatively small sample of work to allow for the comparison of marking standards. The exercise can take place at appropriate stages during the course and has three beneficial effects: it helps to bring about greater comparability in the marking standards; it may identify at an early stage any teachers whose standards are out of line with that of their colleagues; and it alleviates a heavy marking load at the end of the course.

Where the work for a unit has been marked by more than one teacher in a consortium, standardisation of marking should normally be carried out according to one of the following procedures:

**Either** a sample of work which has been marked by each teacher is re-marked by the teacher who is in charge of internal standardisation – normally the Domain Assessor;

**Or** all the teachers responsible for marking a component exchange some marked work (preferably at a meeting led by the Domain Assessor) and compare their marking standards.

Where standards are found to be inconsistent, the discrepant teacher(s) should make adjustments to their marks or re-consider the marks of all candidates for whom they were responsible. The new marks should be checked by the teacher in charge of internal standardisation.

Following completion of the marking and of internal standardisation, the coursework must be retained within the consortium and not returned to the candidates.

Consortia should retain evidence that internal standardisation has been carried out.

## **Annexe F: Learning outcomes and assessment criteria for each unit**

The following sections state the learning outcomes and assessment criteria for each unit that are presented on the National Database of Accredited Qualifications, NDAQ. Each section outlines the intermediary stage in generating the marking grid from the learning outcomes via assessment criteria.



## Unit title: Level 3 Unit 1 Investigating Engineering Business and the Environment

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Know how an engineering business is structured and how it operates	<p>Identify types of engineering companies, the sectors in which an engineering company operates, explain the functions within an engineering company and review its structure and organisation.</p> <p>Identify, describe and explain the types, form, content and flow of information that are essential for the operation of an engineering company.</p>
LO.2	Know about internal and external factors that affect the way in which an engineering business operates	<p>Identify and describe the internal and external factors that affect the way in which an engineering company operates.</p> <p>Explain strategic decisions made by an engineering business that arise from economic, environmental or social factors.</p>
LO.3	Know about and apply financial and planning concepts, and costing and planning techniques	<p>Identify, explain and apply appropriate financial concepts and costing techniques to determine cost-effectiveness of an engineering activity.</p> <p>Identify, explain and apply planning concepts and techniques and determine the critical path and time required to perform an engineering activity.</p>
LO.4	Know the importance of legislation concerning health and safety including a risk assessment for an engineering activity	Explain health and safety legislation and other regulations and the related control measures that apply to engineering activities, including the use of risk assessments and how they are carried out.

## Unit title: Level 3 Unit 2 Applications of Computer Aided Designing

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Know about computer systems and methods of data storage	Identify the component parts of a typical computer system, giving a description of their functions, roles and relationships with data storage and review typical applications of data storage methods.
LO.2	Know about the capabilities of design, presentation, testing and analysis software packages and how they are used as tools within engineering	Explore and state the capabilities of commercially available software selected for the purpose of design, presentation, testing and analysis and give examples of their use in engineering [IE3], preparing a case study to illustrate how software is used in pre-production.
LO.3	Be able to use a CAD package to produce 2D drawings	Produce a 2D CAD working detail drawing and an assembly drawing using orthographic and isometric projections and produce circuit and system diagrams using representations and symbols.
LO.4	Be able to use design software to produce 3D models for use as presentation drawings or as data for other software uses	Produce a 3D representation of a component that requires the drawing, surfaces and model to be defined by methods other than extrusion of 2D shapes and manipulate the model to display different orientations of the component [CT1].
LO.5	Be able to use testing and analysis simulation software as a design support tool	Conduct a virtual operational performance test or material analysis of a product or material for a given purpose and present the results for analysis, review for issues of non-compliance [CT5].

**PLTS:** This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills which are embedded in the assessment of this unit. By achieving the criteria, learners will have demonstrated effective application of the referenced elements of the skills. *Annexe B* of this document lists the personal, learning and thinking skills and their elements.

<b>Key</b>	IE – independent enquirers CT – creative thinkers RL – reflective learners TW – team workers SM – self-managers EP – effective participators
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## Unit title: Level 3 Unit 3 Selection and Application of Engineering Materials

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Know about the structure and their effects on the mechanical properties of engineering materials	Describe crystal lattice and polymer structures and their effects on the properties of metals and plastics.
LO.2	Know about the forms of supply, applications and the selection of engineering materials	Describe and review the properties, a form of supply and an application of a given metal a given polymer and a given composite material  Select and review the use of an information source to select material for a given purpose [IE4].
LO.3	Know about the impact of processing on the structure of engineering materials	Describe work hardening and grain growth in metals and the glass transition temperature in polymers and the related micro-structure changes that occur.  Distinguish between annealing, quench hardening and tempering, case hardening and precipitation hardening, identify the applicable materials and state the property and structural changes that occur.
LO.4	Know about the effects of loading, modes of failure and carry out testing of engineering materials	Carry out appropriate calculations relating to the loading of engineering materials.  Describe the modes of failure and the characteristics of appearance that can occur in engineering materials and the related service conditions under which they can occur.  Carry out a destructive and a non-destructive material test and record and review the test data [SM2] and describe possible industrial settings.

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## Unit title: Level 3 Unit 4 Instrumentation and Control Engineering

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Understand the difference between analogue and digital signals and the need for various forms of transmission media	Describe the fundamental characteristics of analogue and digital signals, explain the different types of and need for transmission media and explain the methods of connecting and interfacing analogue and digital signals and the process of signal conversion.
LO.2	Know about the use of sensors, transducers and instrumentation displays in instrumentation and control applications	Explain the role and operation of digital and analogue sensors, transducers and displays in instrumentation and control applications, review an instrumentation and control system and explain the code conversion and display technology used.
LO.3	Understand the principles and difference between open loop and closed loop systems	Describe the principles of open and closed loop control systems, explain a practical closed loop system and review the operation of a control system that incorporates proportional, integral and derivative control.
LO.4	Understand the use of programmable logic controllers in instrumentation and control applications	Describe a PLC system, explain its advantages and disadvantages and its operation and program it to carry out a single specified task. Review a PLC system and its industrial application.
LO.5	Understand applications of control engineering	Review an application of control engineering and draw a block diagram of the system. Indicate and review the types and use of sensors, transducers, actuators, signal conditioning and displays.

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## Unit title: Level 3 Unit 5 Maintaining Engineering Plant, Equipment and Systems

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Know about the cost of maintenance and the consequences of plant, equipment or system failure including the effects on production	Describe and review the consequences of failure for given plant, equipment or a system and describes the effects on production, customer expectation and corporate image.  Describe how the costs of maintenance are represented for given plant, equipment or a system and review the use of accurate cost records in a maintenance environment.
LO.2	Be able to deploy effective maintenance strategies when planning a maintenance activity	Describe and review two given types of maintenance strategies.  Develop and review a maintenance plan giving consideration to alternative approaches [EP3, SM3] and the appropriate methods used to present the plan [RL6] for a given type of maintenance strategy.
LO.3	Know how the data gathered from monitoring the performance and condition of engineering plant, equipment or system can be used	For a given monitoring technique describe how data would be collected and interpreted and review the use of data when considering physical, cost related, and other aspects that show performance and condition of engineering plant, equipment or systems.
LO.4	Be able to carry out a risk assessment and follow a maintenance plan using documentation for a maintenance activity on a closed loop engineering system	Complete and review a risk assessment [SM4], then follow a given maintenance plan deploying other relevant safety conditions and use supporting documentation to carry out appropriate maintenance activities on a closed loop engineering system.

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## Unit title: Level 3 Unit 6 Investigating Modern Manufacturing Techniques Used in Engineering

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Understand the differences between traditional and modern manufacturing production systems used within engineering industries	Explore and review the differences between traditional and modern manufacturing production systems including lean manufacturing in terms of number and volume of products manufactured [IE3], give examples of typical products for each system.
LO.2	Understand how different types of manufacturing processes utilise computer aided manufacturing systems	Explain and review the processes and level of computer-aided-manufacturing and automation used to manufacture selected products in two different engineering manufacturing industries.
LO.3	Be able to plan for the production of an engineered product for industry	Produce a project network analysis [SM3] to show the critical path [EP3] for the production of a quantity of the same engineered product and develop and review a production plan and a schedule.
LO.4	Be able to work in a team and apply quality control and quality assurance systems	Work in a team [TW1, TW2] and collect sufficient and appropriate data from an engineering manufacturing process, produce appropriate charts to control the output against a required standard and explain quality control and assurance systems and propose ways to ease unwanted process variations.

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## Unit title: Level 3 Unit 7 Innovative Design and Enterprise

Learning outcome number	Learning outcome	Assessment criteria
	The learner should:	The learner can:
LO.1	Know how a successful new product evolves	Identify products that are recognised as being innovative and compare them to traditional counterparts in terms of their design/operation, method of manufacture, marketing approach [IE3]; explain the features that have led to one of the products being regarded as innovative and the factors that have made it a success.
LO.2	Know about individuals who have become successful engineering entrepreneurs	Identify successful entrepreneurial engineering-based individuals, describe their route to success and identify and review the key factors that led to their success.
LO.3	Understand how engineering activities impact on society and the environment	Show how engineering activities have had an impact in different ways on social activity and behaviour and the related environmental issues.
LO.4	Be able to produce or improve designs in an innovative way	Produce and present arguments for a new design, or an improvement to an existing one that displays innovation in terms of at least two key product features [CT1, CT5].
LO.5	Know about opportunities for success when bringing a new product to market	Describe how new products can be brought to market and review the ways in which two innovative products, one that was a commercial success and one that failed, were brought to market and reasons for their success or failure.

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## Unit title: Level 3 Unit 8 Mathematical Techniques and Applications for Engineers

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Know how to use algebraic methods to solve engineering problems	<p>Simplify and evaluate expressions involving the use of indices.</p> <p>Solve a linear equation by plotting a straight line graph from given data and use it to deduce the gradient, intercept and equation of the line.</p> <p>Solve problems involving logarithms.</p> <p>Solve problems involving exponential growth and decay.</p> <p>Use factorisation to simplify mathematical expressions.</p> <p>Solve quadratic equations by factorising or by using the formula method.</p>
LO.2	Be able to use trigonometric methods to solve engineering problems	<p>Define and determine the sine, cosine and tangent of a given angle in a given right-angled triangle and solve problems involving right angled triangles.</p> <p>Use standard formulae to find surface areas and volumes of regular solids.</p> <p>Sketch trigonometric functions over a complete cycle and solves trigonometric equations.</p> <p>Convert radians to degrees and degrees to radians and solve problems involving circular measure.</p> <p>Apply the sine and cosine rules to the solution of trigonometric equations.</p> <p>Solve problems involving angular motion, converting between units expressed in terms of revolutions per second, revolutions per minute and radians per second (as appropriate).</p>
LO.3	Be able to use statistical methods to display engineering data	<p>Generate ideas to produce appropriate statistical diagrams, histograms and frequency curves for a given set of statistical data.</p> <p>Determine the mean, median and mode for a given set of statistical data.</p> <p>Explain the significance of mean, median and mode for a given set of statistical data as a measure of central tendency.</p>

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.4	Know how to apply elementary calculus techniques to solve engineering problems	<p>Determine the gradient of a curve by constructing a tangent at different points. Identify turning points (maximum, minimum and inflexion) and infers that the gradient will be zero at such a point.</p> <p>Apply the basic rules of calculus to a polynomial or trigonometric expression in order to obtain the derivative function.</p> <p>Apply the basic rules of calculus to a polynomial or trigonometric expression to obtain the integral function.</p>

## Unit title: Level 3 Unit 9 Principles and Application of Engineering Science

Learning outcome number	Learning outcome The learner should:	Assessment criteria The learner can:
LO.1	Be able to apply mechanical principles to determine the effects of forces in engineering systems	Solves systems of coplanar forces, apply the principle of moments to a loaded system and determine the conditions for static equilibrium of a loaded beam and determines beam reactions [IE4].
LO.2	Be able to apply mechanical principles to determine the effects of motion, work and energy transfer in engineering systems	Solve practical engineering problems involving linear and angular motions, and friction; apply Newton's laws of motion and the principles of conservation of momentum and energy [IE4].
LO.3	Be able to apply electrical principles to determine the effects of electric charge and current and determine the voltage, current, resistance and power in electrical circuits	Solve practical engineering problems involving direct current and alternating current circuits and apply the basic principles of electro magnetism and electro magnetic coupling [IE4].
LO.4	Be able to apply the principles of heat and thermodynamics to determine the effects of expansion and compression of gases and energy transfer in engineering systems	Solve practical engineering problems involving heat, energy transfer, thermodynamics and the expansion and compression of gasses [IE4].
LO.5	Know about the principles of chemistry and the effects of chemical processes and reactions	Describe and explain the chemical composition, properties and industrial applications, reactions and methods used for producing arenes and phenols and describe and explain industrial processes associated with petrochemicals.
LO.6	Be able to apply the principles of fluid dynamics to determine the effects of viscosity and the forces acting in hydrostatic systems	Solve practical engineering problems involving fluids at rest and in motion using fluid flow equations [IE4].

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