Pearson BTEC Level 2 Certificate/Diploma in Engineering Operations (Knowledge)

Specification

BTEC Specialist qualification

First registration September 2020

About Pearson

We are the world's learning company operating in 70 countries around the world with more than 22,500 employees. We provide content, assessment and digital services to schools, colleges and universities, as well as professional and vocational education to learners to help increase their skills and lifelong employability prospects. We believe that wherever learning flourishes so do people.

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All information in this specification is correct at time of publication.

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Summary of changes to
Pearson BTEC Level 2 Certificate and Diploma in Engineering Operations (Knowledge) specification Issue 1
from previous
Pearson BTEC Level 2 Diploma in Engineering Operations (Knowledge) specification Issue 1

Summary of changes made between previous Diploma specification and this Certificate and Diploma specification	**Page number**
A nested Certificate has been added to the specification	1, 4, 5
The reference to Unit 8 not being permissible to take with any of Units 5, 6 and 7 has been removed	6

If you need further information on these changes or what they mean, please contact us via our website at: qualifications.pearson.com/en/support/contact-us.html.

Contents

1 Introducing the qualifications

What are BTEC Specialist qualifications?

BTEC Specialist qualifications are work-related qualifications available from Entry to Level 3. The qualifications put learning into the context of the world of work, giving students the opportunity to apply their research, skills and knowledge in relevant and realistic work contexts. This applied, practical approach means learners build the knowledge, understanding and skills they need for career progression or further study.

Qualifications purpose

The Pearson BTEC Level 2 Certificate in Engineering Operations (Knowledge) is for learners who are working in, or who are intending to work in the engineering sector. The qualification is designed to support the off-the-job training and development of apprentices on the engineering operative apprenticeship programme.

It is also for those individuals who are not on an apprenticeship programme but who wish to achieve a qualification to prepare for employment or progress to further qualifications in the engineering and manufacturing sector.

The Pearson BTEC Level 2 Certificate in Engineering Operations (Knowledge) is suitable for learners to:

- develop knowledge related to basic engineering related topics such as Computer Aided Design and basic engineering maintenance
- develop skills related to basic manual and CNC machining as well as additive manufacturing
- achieve a qualification to prepare for employment
- achieve a nationally-recognised Level 2 qualification
- develop own personal growth and engagement in learning
- develop confidence and readiness for the apprenticeship end-point assessment.

The Pearson BTEC Level 2 Diploma in Engineering Operations (Knowledge) is for learners working, or who are intending to work in, an engineering operative job role. The qualification is designed to support the off-the-job training and development of apprentices on the engineering operative apprenticeship programme. It is also for those individuals who are not on an apprenticeship programme but who wish to achieve a qualification to prepare for employment. The Diploma also allows learners to complete a wider range of units to begin to progress into a more specialised area of engineering.

The Diploma gives learners the opportunity to:

- develop the technical knowledge and understanding that underpins competence in an engineering operative role.
- learn about a range of transferable skills and professional attributes that support successful performance in the workplace
- be able to focus on a more specialised area of engineering
- achieve a nationally-recognised Level 2 qualification
- develop confidence and readiness for the apprenticeship end-point assessment.

Apprenticeships

The Level 2 Certificate or Diploma in Engineering Operations (Knowledge) are mandatory requirements within the Engineering Operative Apprenticeship Standard. Learners must achieve the Certificate or Diploma before progressing to the end-point assessment (EPA). The Pearson BTEC Level 2 Certificate and Diploma in Engineering Operations (Knowledge) are both offered by Pearson as part of its apprenticeship offer.

As part of the Apprenticeship Standard, learners must also have achieved English and mathematics at Level 1 (either GCSE or Functional Skills) and ideally have sat the assessment at Level 2 before progressing to the EPA.

Progression opportunities

Learners who achieve either the Certificate or the Diploma can progress to the EPA in the Engineering Operative Apprenticeship. Learners who have met all the specified requirements of the Engineering Operative Apprenticeship can progress to achieving the full apprenticeship certification, which confirms competency in the engineering operative role.

With further training and development, learners can progress to a Level 3 Engineering Technician Apprenticeship or another Level 3 Engineering/STEM related apprenticeship, which will give them the competence to apply for more senior or complex job roles in the sector. After further study at Level 3, learners can apply to be professionally registered as Engineering Technicians (EngTech).

Alternatively, learners who have achieved either the Certificate or the Diploma but who have not completed the full apprenticeship requirements could progress to job roles such as servicing and maintenance operative, fabricator, engineering fitter, multi-disciplined engineering operative, materials, processing and finishing operative, technical support operative and founding/casting operative. They could also progress to other qualifications in the BTEC National suite of qualifications in Engineering at Level 3 or the Pearson BTEC Level 3 in Advanced Manufacturing Engineering.

Industry support and recognition

The Pearson BTEC Level 2 Certificate and Diploma in Engineering Operations (Knowledge) was developed through close collaboration with the Engineering Operative Trailblazer group, Semta, EAL and City and Guilds.

The trailblazer group included the following employers: Roquette UK, William Hare Ltd, JCB, MoveTech, Ministry of Defence, KMF, Severfield (UK) Limited, Royal Armoured Corps, Cooney Marine International, Unipres (UK) Limited, Quinton Major Precision, Renishaw, Siemens, CSPS; and by Semta the Sector Skills Council.

Funding

Qualifications eligible and funded for post-16-year-olds can be found on the funding Hub.

2 Qualification summary and key information

Qualification title	Pearson BTEC Level 2 Certificate in Engineering Operations (Knowledge)
Qualification Number (QN)	603/6351/4
Regulation start date	20/08/2020
Operational start date	01/09/2020
Approved age ranges	16–18 19+
Total qualification time (TQT)	301 hours.
Guided learning hours (GLH)	210.
Assessment	Internal assessment.
Grading information	The qualification and units are graded Pass/Fail.
Entry requirements	No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification.

Qualification title	Pearson BTEC Level 2 Diploma in Engineering Operations (Knowledge)
Qualification Number (QN)	603/4722/3
Regulation start date	01/07/2019
Operational start date	01/09/2019
Approved age ranges	16–18 19+
Total qualification time (TQT)	525 hours.
Guided learning hours (GLH)	360.
Assessment	Internal assessment.
Grading information	The qualification and units are graded Pass/Fail.
Entry requirements	No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification.

3 Qualification structures

Pearson BTEC Level 2 Certificate in Engineering Operations (Knowledge)

The requirements outlined in the table below must be met for Pearson to award the qualification.

Minimum number of units that must be achieved	4
Number of mandatory units that must be achieved	1
Number of optional units that must be achieved	3

Pearson BTEC Level 2 Diploma in Engineering Operations (Knowledge)

The learner will need to meet the requirements outlined in the table below before Pearson can award the qualification.

Minimum number of units that must be achieved	7
Number of mandatory units that must be achieved	1
Number of optional units that must be achieved	6

Unit number	Mandatory unit	Level	Guided learning hours
1	Working in an Engineering Environment	2	60

Unit number	Optional units	Level	Guided learning hours
2	Engineering Techniques	2	60
3	Engineering Mathematics and Science Principles	2	90
4	Business Improvement Techniques	2	50
5	Principles of Turning and Milling **(If chosen, cannot select Unit 6 or Unit 7)**	2	80
6	Grinding Techniques **(If chosen, cannot select Unit 5 or Unit 7)**	2	50
7	Principles of Computer Numerical Control (CNC) Milling and Turning **(If chosen, cannot select Unit 5 or Unit 6)**	2	80
8	Computer Aided Design (CAD)	2	90
9	Electrical and Electronic Principles	2	50
10	Fabrication and Welding Principles	2	50
11	Manual Welding Techniques	2	50
12	Non-fusion Thermal Joining Methods	2	50
13	Engineering Maintenance Safety Practices	2	50
14	Engineering Maintenance Planning	2	50
15	Engineering Materials Processes	2	50
16	Plan and Carry out a Project in Engineering	2	50
17	Engineering Manufacturing Techniques	2	50
18	Engineering Design Techniques	2	50
19	Additive Manufacturing (3D Printing)	2	50

4 Assessment requirements

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

Units	Assessment method
All units	Internal assessment (centre-devised assessments).

Language of assessment

Learners must use English only during the assessment of these qualifications.

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

Further information on the use of language in qualifications is available in our *Use of languages in qualifications policy,* available on our website, qualifications.pearson.com.

Internal assessment

Internally assessed units are subject to standards verification. This means that centres set and mark the final summative assessment for each unit, using the examples and support that Pearson provides.

To pass each internally assessed unit, learners must:

- achieve all the specified learning outcomes
- satisfy all the assessment criteria by providing sufficient and valid evidence for each criterion
- prove that the evidence is their own.

Centres must ensure:

- assessment is carried out by assessors with relevant expertise in both the occupational area and assessment. For the occupational area, this can be evidenced by a relevant qualification or current (within three years) occupational experience that is at an equivalent level or higher than this qualification. Assessment expertise can be evidenced by qualification in teaching or assessing and/or internal quality assurance or current (within three years) experience of assessing or internal verification

- internal verification systems are in place to ensure the quality and authenticity of learners' work, as well as the accuracy and consistency of assessment.

Learners who do not successfully pass an assignment, are allowed to resubmit evidence for the assignment or to retake another assignment.

Assessment of knowledge units

To pass each knowledge unit, learners must independently complete assignment(s) that show that the learning outcomes and assessment criteria for the unit have been met.

Format of assignments for knowledge units:

- all learning outcomes and assessment criteria must be covered
- assignments can include both practical and written tasks
- assignments are independently completed as a distinct activity after the required teaching has taken place
- the brief is issued to learners with a defined start date, a completion date and clear requirements for the evidence they are required to produce
- all or parts of units can be combined into a single assignment. Learning outcomes must not be split into more than one assignment.

Each unit contains suggested tasks that centres can use to form the basis of assignments for learners to complete. It is expected that centres will contextualise these and ensure that the final version is checked by their internal verifier.

5 Centre recognition and approval

Centres must have approval prior to delivering or assessing any of the units in this qualification.

Centres that have not previously offered BTEC Specialist qualifications need to apply for, and be granted, centre recognition as part of the process for approval to offer individual qualifications.

Existing centres will be given 'automatic approval' for a new qualification if they are already approved for a qualification that is being replaced by a new qualification and the conditions for automatic approval are met.

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

Approvals agreement

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

Centre resource requirements

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

- appropriate physical resources (for example IT, learning materials, teaching rooms) to support the delivery and assessment of the qualification
- suitable staff for delivering and assessing the qualifications (see *Section 4 Assessment requirements*)
- systems to ensure continuing professional development (CPD) for staff delivering and assessing the qualifications
- health and safety policies that relate to the use of equipment by learners
- internal verification systems and procedures (see *Section 4 Assessment requirements)*
- any unit-specific resources stated in individual units.

6 Access to qualifications

Access to qualifications for learners with disabilities or specific needs.

Equality and fairness are central to our work. Our *Equality, diversity and inclusion policy* requires all learners to have equal opportunity to access our qualifications and assessments, and that our qualifications are awarded in a way that is fair to every learner.

We are committed to making sure that:

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

For learners with disabilities and specific needs, the assessment of their potential to achieve the qualification must identify, where appropriate, the support that will be made available to them during delivery and assessment of the qualifications.

- Centres must deliver the qualifications in accordance with current equality legislation. For full details of the Equality Act 2010, please visit www.legislation.gov.uk

Reasonable adjustments and special consideration

Centres are permitted to make adjustments to assessment to take account of the needs of individual learners. Any reasonable adjustment must reflect the normal learning or working practice of a learner in a centre or a learner working in the occupational area.

Centres cannot apply their own special consideration – applications for special consideration must be made to Pearson and can be made on a case-by-case basis only.

Centres must follow the guidance in the Pearson document Guidance for reasonable adjustments and special consideration in vocational internally assessed units.

7 Recognising prior learning and achievement

Recognition of Prior Learning (RPL) considers whether a learner can demonstrate that they can meet the assessment requirements for a unit through knowledge, understanding or skills they already possess and so do not need to develop through a course of learning.

Pearson encourages centres to recognise learners' previous achievements and experiences in and outside the workplace, as well as in the classroom. RPL provides a route for the recognition of the achievements resulting from continuous learning.

RPL enables recognition of achievement from a range of activities using any valid assessment methodology. If the assessment requirements of a given unit or qualification have been met, the use of RPL is acceptable for accrediting a unit, units or a whole qualification. Evidence of learning must be sufficient, reliable and valid.

Further guidance is available in our policy document *Recognition of prior learning policy and process*, available on our website.

8 Quality assurance of centres

For the qualification in this specification, the Pearson quality assurance model will consist of the following processes.

Centres will receive at least one visit from our Standards Verifier, followed by ongoing support and development. This may result in more visits or remote support, as required to complete standards verification. The exact frequency and duration of Standards Verifier visits/remote sampling will reflect the level of risk associated with a programme, taking account of the:

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

Following registration, centres will be given further quality assurance and sampling guidance.

For further details, please see the work-based learning quality assurance handbooks, available in the support section of our website:

- Pearson centre guide to quality assurance – NVQs/SVQs and competence-based qualifications
- Pearson delivery guidance & quality assurance requirements – NVQs/SVQs and competence-based qualifications.

9 Units

This section of the specification contains the units that form the assessment for the qualification.

For explanation of the terms within the units, please refer to *Section 14 Glossary*.

It is compulsory for learners to meet the learning outcomes and the assessment criteria to achieve a Pass. Content is compulsory unless it is provided as an example and is therefore marked 'e.g.'. All compulsory content must be delivered, but assessments may not cover all content.

Where legislation is included in delivery and assessment, centres must ensure that it is current and up to date.

Unit 1: Working in an Engineering Environment

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

Unit introduction

Working in an engineering environment can give you a fulfilling and rewarding career. You will have opportunities to develop mental and practical skills, and expertise in the workplace, whether in a small enterprise or in a multinational company with a global influence. The engineering workplace, however, can present hazards, which need to be understood and respected so that you and others around you stay safe.

In this unit, you will explore the different types of engineering organisation and how they develop their workforce to ensure that they have the skills they need to remain economically competitive. You will explore current health and safety legislation, and how to work safely when using tools and equipment for fitting and assembly tasks.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the requirements of an engineering organisation in meeting health and safety legislation and regulations	1.1	Describe the principal provisions of the Health and Safety at Work etc. Act 1974 (HASAW)
		1.2	Describe the safe working practices to be followed and what to do in case of an emergency in an engineering environment
		1.3	Explain how the 'six pack' regulations contribute to a safe and effective workplace
		1.4	Explain how current legislation affects the health and safety of employers, employees and the public
		1.5	State the mandatory procedures for reporting accidents or injuries in an engineering environment
2	Understand the roles and responsibilities of both employers and employees in the continuous development of skills and working relationships	2.1	Explain the roles and responsibilities of both the employer and employee in the development of skills and working relationships
		2.2	State the benefits of continuous development to both employees and their workplace
		2.3	Describe the types of employee development procedures that are in used in the workplace
		2.4	State the procedures in the workplace that must be followed in order to raise a grievance

Learning outcomes		Assessment criteria	
3	Understand the internal and external environments associated with the operations of an engineering organisation	3.1	Describe the departmental functions in an engineering organisation
		3.2	Describe the different types of engineering organisation in the United Kingdom
		3.3	Explain the factors that influence change in the engineering industry
		3.4	Explain the effects of industrial change on the requirements of the workforce
		3.5	Describe the different categories of employee in the engineering industry
		3.6	Describe the different organisational structures found in the engineering industry
4	Understand the requirements of engineering fitting and assembly operations	4.1	Identify the tools and methods employed in fitting and assembly operations
		4.2	Describe the safe use of work holding equipment
		4.3	Describe the purpose of tools used in fitting and assembly operations
		4.4	Describe the purpose of the standards and requirements applied to fitting and assembly in an engineering organisation
		4.5	Describe how the fitting and assembly features are shown in engineering drawings

Unit content

What needs to be learned
Learning outcome 1: Understand the requirements of an engineering organisation in meeting current health and safety legislation and regulations

1A Principal provisions of legislation and regulations that apply to engineering environments
• All legislation cited in the content is current at the time of publication. The most recent legislation must be taught and assessed.
• The purpose of the Health and Safety at Work etc. Act 1974 (HASAWA).
• The purpose and content of the Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended).
• The purpose and content of the Health and Safety (Safety Signs and Signals) Regulations 1996.
• The purpose and content of the 'six pack' Regulations':
  ○ Management of Health and Safety at Work Regulations 1999
  ○ Manual Handling Operations Regulations 1992, amended 2002
  ○ Display Screen Equipment Regulations 1992
  ○ Workplace (Health, Safety and Welfare) Regulations1992
  ○ Provision and Use of Work Equipment Regulations 1998
  ○ Personal Protective Equipment (PPE) Regulations 2002.
• The safe use of tools and equipment, in accordance with Provision and Use of Work Equipment Regulations (PUWER) 1998.
1B Safe working practices associated with the operations within an engineering environment
• Safe working procedures with electricity, procedures to be followed in the event of electric shock (isolation from the electrical supply, isolation of the electrical supply and resuscitation procedures).
• Fire prevention and emergency procedures (role of nominated person, fire action plan, training, fire exits, escape routes, assembly points).
• Factors that influence the choice of Personal Protective Equipment (PPE) for given situations, e.g. noise levels, hazardous materials.

What needs to be learned

Learning outcome 1: Understand the requirements of an engineering organisation in meeting current health and safety legislation and regulations

1C How current health and safety legislation affects employers, employees and the public

- Responsibilities of the employer and the employee in relation to current health and safety legislation:
  - employers (to protect health, safety and welfare of their employees and other people affected by their organisation by assessing risk, minimising risk of identified hazards, providing safe systems of work, PPE, adequate welfare and hygiene facilities, suitable supervision, training, maintaining equipment, avoiding the need for activities that pose risk of injury)
  - employees (to ensure own activities do not put others at risk, including colleagues and members of the public, to follow safe systems of work and control measures provided by employer, to attend training).

1D Mandatory procedures applicable to the reporting of accidents or injuries within an engineering working environment

- Mandatory procedures applicable to the reporting of accidents or injuries within an engineering working environment in accordance with the Reporting of Injuries Diseases or Dangerous Occurrences Regulations 1995 (RIDDOR).

What needs to be learned

Learning outcome 2: Understand the roles and responsibilities of both employers and employees in the continuous development of skills and working relationships

2A Responsibilities of both the employer and employee in thedevelopment of skills and working relationships

- Employer: company induction, appraisals, Investors in People (IiP), ongoing feedback.
- Employee: attend training, follow organisational procedures, review own performance, continuous personal development (CPD), mentoring/buddy system.

2B Roles and responsibilities of both employer and employee in the process of personnel development

- Importance of developing and maintaining effective working relationships in the working environment and the results if these relationships break down, including with peers, with subordinates, with management, with outside people/organisations.
- Benefits of continuous personal development: keeping skills and knowledge up to date, goal creation, career progression, contributes to effective working.
- Main factors in the process of developing a Personal Development Plan for a given situation by identification of specific goals, development of a plan of action, monitoring performance, evaluating effectiveness.
- Stages and actions taken by both the employer and employee in discipline and grievance procedures, e.g. verbal notice, written statement, face-to-face meeting, right of appeal.

What needs to be learned

Learning outcome 3: Understand the internal and external environments associated with the operations of an engineering organisation

3A Departmental functions within an engineering organisation

- Research and development, design, purchasing, production, quality control, sales, marketing, customer service, human resources.

3B Types of engineering organisations in the United Kingdom

- For example, multinational, national, regional, small and medium enterprises (SMEs), jobbing-shops, sole traders.

3C Factors that influence change within the engineering industry

- For example, market forces, the global marketplace, advances in technology, environmental factors, reduced demand for products.

3D Effects of industrial change on the requirements of the workforce

- How industrial change affects the requirements of the workforce, e.g. transferable skills, technological demand of job roles, flexible working patterns, professional development, synergy between internal departments.

3E Categories of employees within the engineering industry

- Types of employee within the engineering industry, in terms of:
  - academic/vocational requirements
  - training and experience, e.g. skilled, semi-skilled, unskilled (operator, technician), apprentices, management, professional.

3F Types of organisational structures within the engineering industry

- For example, flat, hierarchical, matrix.

What needs to be learned

Learning outcome 4: Understand the requirements of engineering fitting and assembly operations

4A Tools and methods employed in fitting and assembly operations

- Tools and their uses in fitting and assembly operations, e.g. drills, saws, files, hole threaders.
- Types of measuring equipment used during fitting and assembly operations to ensure compliance with specifications, e.g. tape measure, micrometre, vernier callipers.
- Typical procedures that are commonly used during fitting and assembly operations, including: marking out, drilling, sawing, filing, threading holes, riveting.

4B Safe use of work holding equipment

- Procedures that must be followed to safely use typical work holding equipment found in an engineering environment, including:
  - selecting the correct device for the job
  - pre-use inspection
  - appropriate manual handling techniques (single person or with assistance)
  - correct operation of the work holding device, e.g. correct assembly of a vice to a pillar drill
  - post-use inspection
  - typical methods used to prevent damage to the workpiece while using work holding equipment.

4C Purpose of the tools used in fitting and assembly operations

- Using appropriate tools and equipment to produce an assembly to given specification.
- Types of cutting tool materials and their properties, e.g. high-speed steels (HSS), tungsten carbide, diamond, cubic boron nitride.
- Typical cutting tools, including twist drills, machine and hand reamers, counter bores and counter sinks, hand files.

4D Standards and requirements applied to fitting and assembly

- Role and purpose of The British Standards Institute (BSI) and International standards (ISO).
- Typical features found on fitting/assembly drawings, e.g. tolerance, limits of size, nominal size, thread size, assembly notes.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need access to:

- case studies on typical engineering business organisations such as SMEs and multinationals
- an engineering workshop with a range of work holding devices.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a pamphlet to share with new employees that explains the principles of workplace health and safety in their engineering organisation. Learners who are not in employment can base their evidence on an egineering environment with which they are familiar. Learners will:

1. describe the principal provisions of the Health and Safety at Work etc. Act (1974) in relation to the engineering workplace. Learners must include details of how the provisions protect those in the engineering workplace (AC1.1)
2. describe the procedures to be followed in the event of an electric shock and in the case of a fire in the engineering workplace. Learners must provide clear details of the actions that must be taken in both instances (AC1.2)
3. explain how each of the 'six pack' regulations contribute to a safe and effective workplace. For each of the regulations, learners must give **one** detailed example of their use within an engineering context (AC1.3)
4. explain the main requirements of at least **three** different pieces of health and safety legislation. For each piece of legislation, learners must include **three** detailed examples of how it affects employers, employees and the public in relation to the engineering workplace (AC 1.4)
5. state the procedures to be followed in the engineering workplace when reporting accidents and incidents (AC1.5).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce a leaflet to share with their new apprentices that describes the importance of continuous development and working relationships in the engineering workplace. Learners will:

1. explain **two** responsibilities of the employer and **two** responsibilities of the employee in the development of an effective workplace. For each responsibility, learners must include **one** detailed reason for how they contribute to an effective workplace (AC2.1)
2. state **two** benefits to employees and **two** benefits to their workplace of continuous development (AC2.2)
3. describe the types of employee development procedures that are in use in the workplace. For example, learners could describe their apprenticeship induction to the company, including how they are supported on a daily basis in the workplace (AC2.3)
4. state the procedures in their workplace that must be followed in order to raise a grievance (AC2.4).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a short presentation to share with their work colleagues that details the types of engineering organisation that exist using given case studies. Learners will:

1. describe two different types of engineering organisation, such as a multinational and an SME. Learners must include details of:
    - the departmental functions in the two organisations, including details of the purpose of each departmental function (AC3.1)
    - the types of each organisation (AC3.2)
    - the categories of employees in each organisation (AC3.5)
    - the structures of each organisation (AC3.6)
2. explain how two factors could influence change in the engineering industry with one valid example for each factor (AC3.3)
3. explain two effects of industrial change on the requirements of the workforce with one valid reason for each. (AC3.4)

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners refer to a practical fitting and assembly task they have undertaken and a logbook they have completed demonstrating the use of typical tools and procedures employed in fitting and assembly processes. Where possible, learners undertake these activities within their own workplace, or if they are not in employment, in a realistic work environment.

Learners will:

1. use photographic and written evidence showing the procedures, tools and measurement equipment to be used during the practical activities and which gives details of the safe use of work holding devices and appropriate tooling during the practical activities (AC4.1, 4.2)
2. describe the purpose of the tools required to complete the fitting/assembly exercise (AC4.3)
3. describe the purpose of engineering standards used in their own engineering organisation. Learners must name standards used and outline the areas they cover. (AC4.4)
4. describe three fitting/assembly features that can be found in engineering drawings. Learners present this evidence through annotating a drawing provided by the tutor (AC4.5).

Unit 2: Engineering Techniques

Level: 2

Unit type: Optional

Assessment type: Internal

Guided learning hours: 60

Unit introduction

In this global economy, parts for complex engineering products are manufactured around the world and shipped to a single location for final assembly. Have you ever wondered how these products can be designed in one location, parts manufactured in another and then assembled into final products somewhere else? The answer lies in the ability of skilled engineers to communicate complex technical data in a variety of forms successfully across national boundaries and overcoming language barriers.

This unit will help you to develop your knowledge of the different ways that technical data is communicated, and presented and how information can be used to assist in the marking out and manufacture of components and assemblies. This will help develop your understanding of the engineering applications of ICT. You will learn how components are manufactured through developing an understanding of the importance of marking out and measuring, and of the types of work holding device, tool types and tool holding.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand forms of communication used in engineering	1.1	Describe forms of communication that can be used in engineering
		1.2	Describe the advantages and disadvantages of each form of communication
		1.3	Describe drawing conventions, types, symbols and layouts used in engineering
		1.4	Explain the effects that global manufacturing can have on engineering communications
2	Understand engineering applications of ICT	2.1	Describe the types of ICT application in engineering
		2.2	Explain the benefits of using CAD/CAM software to design and automate the machining process
		2.3	Describe the use of rapid prototyping in engineering design
		2.4	Explain the impact of using rapid prototyping in engineering design
3	Understand the basic tools and techniques used in engineering	3.1	Describe the types of work holding and tool holding used in engineering
		3.2	Describe the types of hand tool used in engineering
		3.3	Describe the types of basic screw thread forms and their uses
		3.4	Describe the methods used to assemble products in engineering

Learning outcomes		Assessment criteria	
4	Understand measurement and marking out techniques	4.1	Describe the types of information used for measuring and marking out component parts and where to find them
		4.2	Describe the types of measurement devices and their uses used in engineering
		4.3	Describe the methods used to measure and mark out parts during manufacture
		4.4	Describe the measurement and marking out tools that can be used in engineering
		4.5	Describe the different methods of supporting workpieces during the measuring and marking out process
		4.6	Describe the types of marking out and measurement errors that can occur during manufacture

Unit content

What needs to be learned
Learning outcome 1: Understand forms of communication used in engineering
1A Forms of communication that can be used in engineering • Verbal, written, electronic and graphical. • Advantages and disadvantages of using individual forms of communication and the problems that can arise when the wrong form is used. • Effects of global manufacture on engineering information communication, e.g. language translation errors, misunderstanding of local drawing conventions, time lag of decision making. **1B Drawing conventions, types and symbols** • First and third angle orthographic projection. • Drawing types, e.g. isometric, oblique, detail, assembly, circuit and wiring, sketches. • Drawing symbols and conventions used in engineering, e.g. line types, hatching, surface finish, tolerances, dimensions.
Learning outcome 2: Understand engineering applications of ICT
2A Benefits/impact of using CAD • Benefits of using computer aided design (CAD), computer aided manufacture (CAM), computer numerical control (CNC) and simulation packages during engineering processes. • Impact of prototyping/3D printing on the engineering design process.
Learning outcome 3: Understand the basic tools and techniques used in engineering
3A Basic tools and techniques used in engineering • Typical work and tool holding methods, e.g. vices, clamps, jigs, fixtures, collets, chucks. • Typical hand tools used in engineering, e.g. hammers, files, hacksaws, taps and dies, marking out tools. • Types of basic screw thread forms, including metric, imperial ACME, Whitworth, unified, and their uses. • Basic methods of work assembly, including thermal, adhesive and mechanical, and their relative advantages / disadvantages.

What needs to be learned

Learning outcome 4: Understand measurement and marking out techniques

4A Measurement and marking out techniques

- Typical sources of measurement information found in engineering, e.g. engineering drawings, circuit drawings, sketches, work instructions, reference charts.
- Typical measurement devices used in engineering and their uses, e.g. rules, tapes, dial test indicators (DTIs), micrometres (metric and imperial).
- Typical methods of marking out used in engineering, e.g. bluing, using templates, using marking datum, hole centres, angular and radial profiles, scribers and scribing blocks.
- Typical aids to marking out, e.g. marking out tables and plates, angle plates, parallel strips, vee blocks, vices.
- Typical errors that can occur during measuring and marking out, including observation errors, recording errors, unit errors, calibration errors.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to engineering workshops including:

- a range of manual machines (lathes, drilling machines, milling machines) and CNC/CAM facilities
- workshop tools, tool holding, work holding facilities, components, measuring instruments, hand and power tools, assembly facilities, marking out facilities
- engineering drawing facilities, including CAD workstations/software
- a learning centre/library.

Visits to engineering workshops would be advantageous in showing small-scale/batch/one-off production techniques.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet to share with colleagues that explains how effective communication of engineering information is of utmost importance. Learners **will**:

1. describe the **four** communication methods that can be used to communicate engineering information. For each method, learners must give **one** suitable examples from the engineering workplace of when it would be used (AC1.1)
2. describe the advantages and disadvantages of using each form of communication to communicate **two** given forms of engineering information. **One** form should include engineering drawings using a standard drawing convention and symbols (AC1.2, 1.3)
3. explain the effects of communicating engineering information outside of national boundaries and the problems that can arise due to misinterpretation. Learners are to research and give **two** examples of engineering failures due to misinterpretation of information where parts are manufactured globally (AC1.4).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet to share with colleagues that describes the types of ICT applications used in engineering. Learners **will**:

1. give a clear account of the types of IT application used in the engineering workplace, including details of the purpose of each application. They will state the benefits of each application, with clear reasons. For example, they could discuss the benefits of using CAD/CAM software to design and automate the machining process (AC2.1, 2.2)
2. describe the use of rapid prototyping in their engineering workplace giving examples of the types of material that can be used. They will also explain the impact rapid prototyping/3D printing could have on their engineering environment, in the short and long term, with at least **two** clear examples (AC2.3, 2.4).

Learning outcomes 3 and 4

To satisfy the assessment criteria for these learning outcomes, learners present annotated photographs/drawings showing how a component is manufactured. The component parts need to be selected carefully to ensure that certain features/ characteristics are present and allow the learning outcomes covered by this assignment to be addressed. Preferably, an assembly of parts, featuring basic screw threads, would be used.

Learners will use evidence from the workplace or a practical/workshop activity undertaken in a realistic work environment and provide a step-by-step commentary of how they used different work holding methods for mechanical assembly, using photographs to support their description.

Learners will:

1. describe the manufacture of three component parts relevant to their own engineering environment. Learners should include details of:
    - **four** typical work and tool holding methods (AC3.1)
    - **three** hand tool types used in the manufacture of the parts, with appropriate details of the tool and its operation in each case. (AC3.2)
    - basic screw thread forms (AC3.3)
    - the basic methods of work assembly. (AC3.4)

Learners will use an engineering assembly drawing to indicate how work is assembled and how thread forms are represented. Learners are expected to demonstrate knowledge of metric, imperial and international thread forms.

2. describe **five** types of information that are used when marking out component parts. Learners must outline how the information is presented (charts, tables, drawings) and how the sources are accessed (AC4.1)
3. describe how **three** types of measurement and **three** types of marking out tools/equipment are used (AC4.2, 4.4)
4. describe **four** marking out techniques. Learners give details of how to carry out each technique through photographs of appropriate practical measuring and/or marking out activities with descriptions of the activities being carried out; typically, learners provide an annotation to each photograph indicating how the activity is carried out, what the tool looks like and how it is used (AC4.3)
5. describe **five** different methods of supporting workpieces during the measuring/marking out process (AC4.5)
6. describe **two** types of error that can occur when measuring and marking out. Learners must include details of the consequences of the errors. Photographic evidence, preferably showing a step-by-step process, with appropriate annotation would be a useful approach (AC4.6).

Unit 3: Engineering Mathematics and Science Principles

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**90**

Unit introduction

Engineers use mathematical and scientific principles, concepts and knowledge of materials in their day-to-day working. This unit gives you the knowledge and understanding you need to apply these principles and concepts to your own engineering role. You will learn about arithmetic and algebra, and apply your knowledge to solve problems. You will learn the principles of statics, kinetics and dynamics, and apply them to solve problems. You will also develop knowledge of the nature of matter and a range of common materials, and their properties. You will learn about how these materials are used and describe how heat treatment has an impact on their performance. You will learn how to identify a range of ferrous, non-ferrous and non-metallic materials, and know about the form in which they are obtained. You will also need to know about the properties that make individual materials suitable for particular tasks.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Be able to use pure maths to solve engineering problems	1.1	Perform arithmetical calculations in an engineering context
		1.2	Manipulate fractions and decimals to solve problems
		1.3	Manipulate ratios, proportions and percentages to solve problems
		1.4	Calculate areas and volumes from given data in an engineering context
		1.5	Calculate simple powers of numbers
		1.6	Apply trigonometry in an engineering context
		1.7	Use algebraic methods to solve linear equations for given engineering problems
2	Be able to use simple graphs in engineering	2.1	Apply the basic principles of graphical representation
		2.2	Use given engineering data to plot a linear graph and establish gradient, intercept and the law connecting the variables in an engineering context
		2.3	Extract data from graphs used in engineering
3	Know the physical and chemical properties of elements and compounds	3.1	Describe the structure of atoms, including atomic number and the composition of atoms
		3.2	Describe chemical elements including their positions in the periodic table.
		3.3	Describe chemical compounds and their physical properties
		3.4	Describe the three 'classical' states of matter

Learning outcomes		Assessment criteria	
4	Know the physics of engineering systems	4.1	Define the terms forces, moments and couples
		4.2	Describe moments and couples using SI units
		4.3	Apply the concepts of stress, strain, elasticity, compression, shear, tension and torsion
		4.4	Describe the basic principles of rotational movement
		4.5	Describe the basic principles of periodic motion
		4.6	Apply the principles of themodynamics
		4.7	Apply the principles of simple mechanical systems
5	Know the classification and properties of engineering materials	5.1	Describe the classifications of materials
		5.2	Describe the basic properties of engineering materials
		5.3	Describe typical forms of material supply
		5.4	Describe typical heat treatment processes
		5.5	Describe the effects of typical heat treatment processes on the mechanical properties of materials

Unit content

What needs to be learned
Learning outcome 1: Be able to use pure maths to solve engineering problems

1A Using arithmetical calculations in an engineering context
• Adding, subtracting, multiplying, dividing using:
  ○ whole and decimal numbers
  ○ fractions (including reducing fractions)
  ○ positive and negative integers.
• Converting units:
  ○ decimals and fractions
  ○ mixed numbers and improper fractions.
• Expressing values to a given number of decimal places.
• Ordering positive and negative integers, decimals and fractions.
• Using the symbols =, ≠, <,>, ≤, ≥.
1B Basic functions within arithmetical calculations
• Power of arithmetic preference – brackets, orders, division, multiplication, addition, subtraction (BODMAS)
• Powers, roots, reciprocals
1C Fractions and decimals
• Fractions in ratio problems; fractions and percentages as operators; decimals to solve problems.
1C Engineering calculations involving ratio and proportion:
• Ratio notation (including reduction to simplest form).
• Dividing given quantities into two parts in a given part: part or part: whole ratio; expressing the division of a quantity into two parts as a ratio.
• Proportion as equality of ratios problems involving direct and inverse proportion.
• Fractions in ratio problems.
• Engineering calculations involving ratio and proportion.
• Applying ratio to real contexts and problems.
• Original value problems.

What needs to be learned
Learning outcome 1: Be able to use pure maths to solve engineering problems

1D Percentages:
• Percentage as 'number of parts per hundred'.
• Percentage changes as a fraction or a decimal.
• Expressing one quantity as percentage of another.
• Comparing quantities using percentages.
• Fractions and percentages as operators.
• Percentage error.
• Problems involving:
  ○ percentage change
  ○ increase/decrease.
1E Applying trigonometry on right angle triangles to engineering contexts
• Pythagoras' theorem.
• Right-angled triangle functions (sine, cosine, tangent).

What needs to be learned

Learning outcome 1: Be able to use pure maths to solve engineering problems

1F Calculating areas and volumes

- Using formulae for calculating areas of shapes:
  - squares
  - triangles
  - rectangles
  - circles and semicircles
  - compound shapes made from squares, triangles, rectangles, circles and/or semicircles.
- Using formulae and appropriate units to calculate volumes of solids:
  - triangular prisms
  - cubes
  - cylinders
  - rectangular prisms
  - cones
  - spheres.
- Using appropriate units to calculate volumes of composite solid shapes made from:
  - rectangles
  - triangles
  - circles and/or semicircles.

1G Calculating simple power of numbers:

- Squares
- Square roots
- Cubes
- Cube roots
- Use of positive integer powers and associated real roots:
  - square
  - cube
  - higher.
- Powers of 2, 3, 4, 5; estimating powers and roots of any given positive number.

What needs to be learned

Learning outcome 1: Be able to use pure maths to solve engineering problems

1H Applying algebraic methods

- Algebraic equations
  - changing the subject of an equation
  - substituting numerical values into algebraic equations
  - solving simple algebraic equations for:
    - single variable
    - systems of linear equations.
- Manipulating algebraic expressions
  - simplifying, changing form of and evaluating algebraic expressions by:
    - collecting like terms
    - multiplying single term over a bracket
    - taking out common factors
    - expanding products of two or more binomials.
- Simple engineering formulae, e.g.
  - (electrical) $V = IR$, $P = VI$, $P = I^2R$
  - (mechanical) $v = u + at$, $s = ½(u + v)t$, $\sigma = F/A$
- Complex engineering formulae e.g.
  - (electrical) $V = V_0 \sin 2\pi ft$, $Xc = ½ \pi fC$, $½QV = ½CV^2$,
  - (mechanical) $s = ut + ½at^2$, $v^2 = u^2 + 2as$, $½mv^2 = mgh$

What needs to be learned

Learning outcome 2: Be able to use simple graphs in engineering

2A Graphical methods:

- Using axes, grid lines, origin, scales.
- Working with coordinates in four quadrants.
- Identifying constant, linear, quadratic, cubic, trignonometric functions.
- Plotting straight line graphs in the coordinate plane (use form y=mx+c).
- Finding equation of line through two given points or one point with given gradient.
- Identifying gradients and intercepts of linear functions:
  - graphically
  - algebraically.

2B Extracting data from graphs used in engineering:

- Interpreting graphs of linear functions.
- Interpreting graphs of quadratic and trignonometric functions.
- Non standard functions to find approximate solutions to:
  - simple kinematic problems
  - speed
  - distance
  - acceleration.
- Calculating or estimating:
  - gradients of graphs
  - areas under graphs.
- Interpreting results in an engineering context e.g.:
  - distance-time graphs
  - velocity-time graphs.

What needs to be learned

Learning outcome 3: Know the physical and chemical properties of elements and compounds

3A Atomic structure:

- Composition of atoms
  - composition of nucleus
  - composition of shells.
- Meaning and representation of:
  - atomic number
  - mass number.
- Meaning of relative atomic mass.
- Relative charge and relative mass of:
  - a proton
  - a neutron
  - an electron.

3B Chemical elements and their positions in the periodic table

- Definition of element.
- Definition of isotope.
- How elements are arranged on the periodic table:
  - by atomic number
  - by classification as metals and non-metals
  - grouping of elements with similar chemical properties in vertical columns
  - connection between number of outer electrons and position of element in periodic table.
- Basic electronic configuration (the electronic configuration of first 10 elements from their positions in the Periodic Table and in the form 2.8).

What needs to be learned

Learning outcome 3: Know the physical and chemical properties of elements and compounds

3C Chemical compounds and their physical properties

- Definitions of:
  - molecule
  - compound
  - mixture.
- Using periodic table to recognise elements and formulae of simple compounds.
- Types of chemical bonding and how they are formed:
  - ionic compounds:
    - ionic bonding and the relationship between ionic charge and the melting point and boiling point of an ionic compound.
  - covalent compounds:
    - the relationship between the bonding pair of electrons and the nuclei of the atoms involved in the bond
    - relationship between the molecular structure of a substance
    - the states of matter and melting/boiling points.
  - metallic crystals:
    - electrical conductivity and malleability of a metal in terms of its structure and bonding.

3D Classical states of matter.

- Arrangement, movement and energy of particles in each of the three states of matter:
  - solid
  - liquid
  - gas.
- Inter-conversions of solids, liquids and gases, terms used for these inter-conversions including sublimation.
- Changes in arrangement, movement and energy of particles during inter-conversions.

What needs to be learned

Learning outcome 4: Know the physics of engineering systems

4A Principle of statics

- Definitions of force, couple and moment.
- Applying formulae related to forces, moments and couples:
  - Force and stress (F=ma=mg)
  - mass/weight relationship (W=mg).
- Apply appropriate method to solve problems:
  - vector representation of forces, moments and couples
  - using and interpreting simple diagrams
  - determination of magnitude and direction of resultant forces.
- Engineering calculations involving forces, moments and couples using SI units
  - force:
    - free-body diagrams to represent forces on a particle or on a rigid body
    - calculations for force, moments, couples
    - use of equation for movement of force.
  - principle of moments:
    - concept of centre of gravity to a body
    - principle of moments to a body in equilibrium.
- Calculations based on concepts of stress, strain, elasticity, compression, shear, tension, torsion
  - basic concepts of, stress, strain, elasticity (including elastic behaviour of material), compression, shear, tention, tortion
  - Hooke's law
  - simple engineering calculations:
    - (tensile/compressive) stress = force/cross-sectional area
    - (tensile/compressive) strain = change in length/original length
    - Young's modulus = stress/strain
    - force-extension and force-compression graphs
    - limit of proportionality, elastic limit, yield point, elastic deformation and plastic deformation, application to graphs.

What needs to be learned

Learning outcome 4: Know the physics of engineering systems

4B Principles of kinetics

- Basic principles of rotational movement:
  - basic principles of uniform circular movement
  - singular displacement in radians and in degrees, conversion between these units
  - definition of angular velocity; equations $v = \omega r$ and $T = 2\pi/\omega$
  - centrifugal/centripetal acceleration; use the equations: $a = v^2/r = r\omega^2$
  - relationship between resultant force (centripetal force) and maintaining circular motion
  - equations for centripetal force: $F = ma = mv^2/r = mr\omega^2$
  - rotational motion calculations.
- Basic principles of periodic motion
  - definition: pendular movement
  - equation for a simple pendulum $T = 2\pi\sqrt{l/g}$
  - basic theories of harmonics, resonance.

What needs to be learned

Learning outcome 4: Know the physics of engineering systems

4C Principles of dynamic systems

- Basic Principles of dynamic systems:
  - units – joule(J) as the unit of energy, watt (W) as the unit of power
  - equations relating power, time and energy transferred or work done:
    - P = E/t
    - P = W/t.
    - Calculations related to dynamic systems
  - efficiency = useful energy output/total energy input
  - efficiency = useful power output/total power input.
- Basic principles of thermodynamic systems:
  - energy transfers from one place to another by conduction, convection, radiation.
- Properties of simple mechanical systems:
  - basic lifting system principles
  - velocity ratio
  - mechanical advantage
  - coefficient of friction, static and dynamic friction, use of the formula F = μR.

What needs to be learned

Learning outcome 5: Know the classifications and properties of engineering materials

5A Classifications of materials:

- Metallic (pure metals, alloys, ferrous, non ferrous).
- Non-metallic materials.
- Composites.
- Natural materials.
- Thermosplastics.
- Thermosetting plastics.
- Ceramics.
- Polymers.
- Smart materials.

5B Basic mechanical properties of engineering materials

- Density.
- Manufacturability.
- Strength (yield, tensile, fracture).
- Elastic limit.
- Proportional limit.
- Ductility.
- Toughness of a range of engineering materials, e.g. low carbon/mild steel, high carbon steel, aluminium/aluminium alloy, brass/brass alloy, composites.

5C Typical forms of material supply

- Forms of engineering stock materials, e.g. sheet, plate, bar, wire, section, hot and cold rolled.

5D Heat treatment processes for metallic materials

- Heat treatment processes, e.g. tempering, annealing, hardening, normalising.
- Effects on the mechanical properties of typical engineering materials, e.g. increased ductility, improved malleability, reduced brittleness, increased toughness, reduced hardness.

Essential information for tutors and assessors

Essential resources

For this unit, centres need a workshop/laboratory with science equipment, relevant material testing equipment and heat treatment facilities.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners complete an assignment that requires them to use arithmetical calculations and algebraic methods to solve given engineering problems. Learners will need to be provided with data and problems to solve by their tutor or employer. The engineering problems should be typical of those encountered in their engineering workplace, or if they are not employed, in an engineering organisation with which they are familiar. The use of a scientific calculator is expected. Learners will:

1. use arithmetical calculations in **two** engineering contexts. Learners must show they can carry out calculations including:
    - adding, subtracting, multiplying, dividing
    - use of whole numbers, decimal numbers, fractions
    - use of positive and negative integers
    - conversion of units
    - basic functions within arithmetical calculations
    - at least **one** calculation related to ratio and/or proportion

- at least **one** calculation related to percentages
- at least **one** calculation related to simple powers of numbers
- apply trigonometry in at least **one** engineering context
- find the areas and volumes of **three** simple and **three** compound shapes from given data in an engineering context.

For example, learners find the number of component blanks that could be stamped out of a sheet of metal and the number of bricks that a builder would need to build a wall of a given length and height. They could then calculate the amount of materials required in **two** engineering contexts, giving the results as both ratios and as percentages. (AC1.1, 1.2, 1.3, 1.4, 1.5, 1.6)

2. use algebraic methods to transpose and solve **two** linear equations and evaluate **one** simple and **one** complex formulae in engineering contexts.

   Learners then transpose **three** simple engineering formulae correctly to change the subject of the equation

   For example, learners could find the resistance of a wire using given values of voltage and current, using the simple equation V=IR. For the complex formulae, learners could be asked to find the time taken using given values of distance, initial velocity and acceleration using the equation $S = ut + 0.5at^2$
   (AC 1.7)

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners complete an assignment that requires them to plot linear and non-linear graphs to solve problems in an engineering context. Tutors or employers must provide learners with data to plot the graphs and the problems to be resolved. These problems should be related to the learner's workplace, or if they are not employed, to an engineering workplace with which they are familiar. They can be related to the same contexts investigated for learning outcome 1, or to new engineering contexts. Learners will:

1. use given engineering data to plot a linear graph and establish gradient, intercept and the law connecting the variables in an engineering context. For example, learners could plot a distance-time graph for a car travelling at constant velocity
2. use given engineering data to plot a non-linear graph and establish gradient, intercept and the law connecting the variables in an engineering context. For example, learners could use given voltage/time data to plot a capacitor discharge graph (AC2.1, 2.2. 2.3)

Learning outcomes 3 and 4

To satisfy the assessment criteria for these learning outcomes, learners complete an assignment demonstrating their understanding of scientific concepts and principles applied to their workplace, or if they are not employed, to an engineering organisation with which they are familiar. Learners will:

1. describe the nature of matter, including the meaning of atomic number and the composition of atoms (AC3.1)
2. define the term 'chemical element', and give a clear account of how elements are arranged on the periodic table. Learners must then outline the basic element structure. (AC3.2)
3. define the terms 'molecule' 'compound' and 'mixture' and describe, giving relevant examples, the **three** types of chemical bonding and their physical properties (AC 3.3)
4. describe the arrangement, movement and energy of particles in the **three** classical types of matter and how these change during inter-conversion between states. (AC3.4)
5. define the terms 'force', 'couple' and 'moment' and give a clear account of how moments and couples act on **two** simple static systems with reference to engineering calculations using the correct SI units (AC4.1, 4.2)
6. describe the concepts of stress and strain and **one** of the following concepts of elasticity, compression, shear, tension and torsion. Learners must relate their descriptions to **two** engineering contexts using the correct SI units (AC4.3)
7. describe the basic principles of rotational motion. Learners must refer to relevant calculations and formulae. (AC4.4)
8. describe the basic principles of periodic motion. Learners must define pendular movement and refer to relevant principles and theories of harmonics and resonance. (AC4.5)
9. describe the energy transferred (work done) in a given time for **one** thermodynamic system and **one** mechanical system (AC4.6, 4.7)
10. calculate the amount of friction in **two** simple engineering contexts using dynamics formulae. (AC4.7).

Learning outcome 5

To satisfy the assessment criteria for this learning outcome, learners produce a written leaflet to present to their apprentice training manager/supervisor, detailing the factors that must be taken into account when selecting materials for a given engineering situation. Learners will:

1. describe the classifications of a range of materials and explain their mechanical properties, using at least **four** examples of materials with different classifications (AC5.1, 5.2)
2. describe the form of material supply for a range of engineering materials used in applications, ensuring that at least **four** forms of supply are evidenced. Electrical conductors supplied in wire form or pipework supplied in tubular form would be typical examples here (AC5.3)
3. describe at least **two** forms of heat treatment process and the effects of these processes on the mechanical properties of given metallic materials, describing a minimum of **three** of these effects for each heat treatment process (AC5.4, 5.5).

Unit 4: Business Improvement Techniques

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Engineers need to know about business improvement techniques to ensure that they are working efficiently and effectively. This knowledge also helps them to support organisations in ensuring that they are competitive in a continuously changing business climate.

In this unit, you will gain knowledge of continuous improvement techniques and their application in the workplace. This will include improving quality and safety, reducing waste and cost, and investigating the improvement cycle. You will understand what is meant by 'workplace organisation', the effects of being disorganised and the benefits of being organised. You will learn about visual management as a business improvement technique. Finally, you will develop an understanding of problem-solving techniques.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand what is meant by 'workplace organisation'	1.1	Describe the methods of improving and sustaining workplace organisation
		1.2	State the purpose and importance of Standard Operating Procedures (SOPs) in relation to workplace organisation
		1.3	Explain the effects of a disorganised work area on the engineering process
2	Understand the continuous improvement process	2.1	Explain what is meant by continuous improvement in an engineering organisation
		2.2	Describe the benefits of continuous improvement in an engineering organisation
		2.3	Describe how the categories of work found in an engineering organisation relate to continuous improvement
		2.4	Describe the categories of waste found in an engineering environment
		2.5	Explain how waste can be reduced or eliminated in an engineering environment
3	Understand visual management techniques and their influence on continuous improvement	3.1	Describe the types of visual management technique that can be used in an engineering organisation
		3.2	Describe the benefits of visual management on an engineering organisation

Learning outcomes			Assessment criteria
4	Understand problem-solving techniques	4.1	Describe the types of problems found in an engineering environment
		4.2	Describe problem-solving techniques used in an engineering environment
		4.3	State the benefits of problem solving in an engineering environment

Unit content

What needs to be learned
Learning outcome 1: Understand what is meant by workplace organisation
1A Methods of improving and sustaining workplace organisation • Use of Standard Operating Procedures (SOPs) to enhance workplace organisation. • Importance of the correct use of storage in the workplace. • Influence of improved floor space utilisation (reduced motion and transportation) on continuous improvement. • Importance of a clean workplace and how the lack of cleaning affects workplace organisation. • Effects that the removal of unused items/equipment has on the working environment, e.g. reduced clutter, improved light levels, improved health and safety. **1B Problems associated with disorganised work environments** • Effects of a disorganised workplace on an engineering organisation, including poor quality, increased costs, reduced efficiency, poor delivery times, poor morale/teamwork, poor health and safety, loss of repeat orders.

What needs to be learned

Learning outcome 2: Understand the continuous improvement process

2A Continuous improvement process

- Definition: the purpose of the continuous improvement process and what it will achieve for an individual business (identifying opportunities for streamlining work and reducing waste), the Plan – Do – Check – Act (PDCA) improvement cycle.

2B Benefits of continuous improvement

- Reduced cost, e.g. production.
- Improved quality, e.g. reduced defects.
- Improved safety, e.g. safe to use.
- Improved working practices, e.g. reduced operator motion.
- Improved delivery, e.g. reduced transportation time, reduced lead time.
- Reduction of waste, e.g. over processing, excess inventory.
- Resource utilisation, e.g. reduced waiting time.
- Improved customer satisfaction, e.g. meeting customer requirements.

2C Categories of work and categories of waste

- The three categories of work undertaken in an engineering organisation – value added, non-value added, waste.
- The effect that each category of work has on the continuous improvement process.
- Different categories of waste, including transport, inventory, motion, waiting, overproduction, over processing, defects, skills/unrecognised people potential.
- Reducing/eliminating waste.

What needs to be learned

Learning outcome 3: Understand visual management techniques and their influence on continuous improvement

3A Types of visual management

- The range of visual management tools that can be utilised in an engineering organisation, e.g. shadow boards, PDCA worksheets, colour coding, Kanban (visual boards), other area-specific types of visual management.

3B Benefits of sound visual management

- Benefits of sound visual management.
- Greater ownership.
- Everyone knows what is going on without needing to ask.
- Simplification of stock taking.
- Improved safety.
- Potential problems are highlighted at an earlier stage.

Learning outcome 4: Understand problem-solving techniques

4A Problems

- Types of problem in work environments, e.g. manufacturing errors, premature replacement of cutting tools, lack of raw materials due to late deliveries from suppliers, production time overrun.
- Benefits of solving problems in a work environment, e.g. improved productivity, improved customer satisfaction, reduction in non-value-added activity, reduction in waste, improved staff morale.
- Consequences of not finding the root causes of problems, e.g. problems will reoccur, 'treating the symptom and not the cause'.

4B Techniques

- Techniques that can be used to identify/solve problems in an engineering organisation, e.g. tally charts, flow charts, histogram/Pareto chart, benchmarking, process mapping, correlation diagram, run diagram, statistical process control, control charts, Gantt charts, root cause paths, value stream maps, Ishikawa diagrams (cause and effect, fishbone), brainstorming, mind mapping, 5 Why analysis.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to case studies on business improvement techniques.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcomes 1 and 3

To satisfy the assessment criteria for these learning outcomes, learners produce a leaflet to share with their colleagues that explains the positive and negative effects of workplace organisation on the engineering workplace. Learners will:

1. give detailed reasons why a disorganised working environment can affect:

- health and safety,
- morale/teamwork
- quality
- profit
- efficiency
- delivery times.

  Learners must give **one** reason for each category (AC1.3)

2. give the purpose of Standard Operating Procedures and **three** reasons for their importance. Learners must then describe **two** other methods of improving and sustaining workplace organisation. (AC1.1, 1.2)
3. define the term 'visual management' and describe **five** types of visual management technique that are applied in their own engineering environment. (AC3.1)
4. describe the benefits of good visual management techniques on their own engineering environment. For the **five** selected techniques, learners must include details of how each benefits the engineering environment (AC3.1, 3.2).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet to share with their colleagues that explains the continuous improvement process in the engineering workplace. Learners will:

1. give a clear account of what is meant by continuous improvement in an engineering organisation and why a company must use a systematic approach to continuous improvement. Learners must include details of the benefits that continuous improvement can bring to a company (AC2.1, 2.2)
2. define the **three** categories of work and for each category give details of how it affects the continuous improvement process (AC2.3)
3. describe the **eight** categories of waste that affect the engineering environment. (AC 2.4)
4. explain how each of these categories can be reduced or eliminated with one example for each category (AC2.5)

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce a short presentation to share with their work colleagues that explains the process of problem solving in the engineering workplace. Learners will need to give a clear account of what is meant by a problem, giving examples of workplace problems that could occur in their chosen environment, such as lack of effective communication from a line manager to a machine operator resulting in a dispute about how many components are to be machined. Learners will:

1. describe **three** types of problem that could occur in the engineering environment. Learners need to provide a clear account of the consequences of not resolving each problem. (AC4.1)
2. describe **five** techniques that can be used to solve the problems. Learners must use appropriate charts and diagrams to illustrate their chosen techniques (AC4.2)
3. give **three** benefits to the engineering environment of solving each of the problems (AC4.3).

Unit 5: Principles of Turning and Milling

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**80**

Unit introduction

Engineers use a large variety of machinery during the manufacture of finished products. By carrying out turning and milling operations, engineers can produce parts with close tolerances and complex shapes. However, the machinery they use can be dangerous to operate.

In this unit, you will learn about how to operate these machines safely while complying with relevant legal requirements and current quality standards. You will explore how centre lathes and vertical milling machines operate. You will also explore the types of cutting tools and work holding devices that can be used. You will then be able to apply this knowledge to carry out practical activities safely, to produce components that comply with appropriate engineering standards.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the equipment and procedures used in turning and milling operations	1.1	Describe the health and safety requirements associated with turning and vertical milling operations
		1.2	Describe the safety precautions relating to the setting and use of a centre lathe and vertical milling machine
		1.3	State the personal protective equipment (PPE) that must be worn when carrying out turning and milling operations
		1.4	Describe centre lathe and vertical milling machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in turning and milling operations	2.1	Describe the functions and operation of the component parts and controls of centre lathes
		2.2	Describe the functions and operation of the component parts and controls of typical vertical milling machines
		2.3	Describe the types of operations that can be carried out on a centre lathe and a vertical milling machine

Learning outcomes		Assessment criteria	
3	Understand the types and applications of cutting tools used in turning and milling operations	3.1	Describe the properties of cutting tool materials used in turning and vertical milling operations
		3.2	Describe cutting tool profiles used in turning and vertical milling operations
		3.3	Describe the function of the rake and clearance of a single point turning tool and a milling cutter
		3.4	Describe cutting techniques used in turning and vertical milling operations
		3.5	Describe the effects of different cuts on the quality of the finished product, production costs and tool life
		3.6	Describe the factors that influence the selection of particular cutting speeds, feed and depths of cut when conducting turning and vertical milling operations
		3.7	State how to calculate the correct spindle speeds using given cutting speeds for turning and vertical milling operations
4	Understand quality standards associated with turning and milling operations	4.1	Describe the current quality standards associated with turning and vertical milling operations
		4.2	Define the engineering terms used in quality standards associated with turning and vertical milling operations
		4.3	Describe methods of measuring surface finish for turning and vertical milling operations
		4.4	Describe the advantages of manufacturing components to recognised engineering standards
5	Know how to select, mount and use work holding equipment used in turning and milling operations	5.1	Identify appropriate work holding devices for turning and vertical milling operations
		5.2	Describe how to mount, secure and align work holding devices for turning and vertical milling operations
		5.3	State standard methods of protecting finished surfaces from marking or damage during turning and vertical milling operations

Learning outcomes		Assessment criteria	
6	Know how to set up and operate a centre lathe and vertical milling machine	6.1	Describe how to set up a centre lathe and vertical milling machine to manufacture components
		6.2	Describe how to use a centre lathe and vertical milling machine to manufacture components
		6.3	State appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the turning and vertical milling operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment and procedures used in turning and milling operations
1A Health and safety requirements associated with turning and vertical milling operations • Duties of employees under current, relevant legislation in relation to turning and vertical milling operations, with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances, environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of a centre lathe and vertical milling machine** • Safety precautions relating to the setting and use of a centre lathe and vertical milling machine, including checking and ensuring that the workpiece is secure and cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping a centre lathe and vertical milling machine under normal conditions and in an emergency. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant. • Use of PPE to include safety glasses, overalls, safety boots, ear defenders.

What needs to be learned

Learning outcome 2: Understand the function of the tooling and equipment used in turning and milling operations

2A Functions and operation of the component parts and controls of a centre lathe

- Component parts of a centre lathe including carriage (saddle and apron), compound slide, cross slide, feed-shaft, guards and covers, including leadscrew and chuck, headstock, lathe bed, leadscrew, tailstock, tool-post.
- Lathe controls including carriage lock, cross feed engagement lever (lateral/tangential), cross slide handle, emergency stop, feed selectors, half-nut lever, longitudinal feed engagement lever, saddle handle, speed selectors, spindle, start/stop lever (forward and reverse), tailstock lock, master isolator.
- Functions of the component parts and controls of a centre lathe, e.g. the tailstock, leadscrew, feed shaft, longitudinal feed engagement lever, cross-feed engagement lever.

2B Functions and operation of the component parts and controls of vertical milling machines

- Component parts of a vertical milling machine including guards, head, motor, drawbar, quill/spindle, quill handle, brake, ram, column, table, saddle, cross (Y axis) traverse handle, power feed (traverse), knee, base.
- Vertical milling machine controls including, start/stop controls, emergency stop, quill lock, speed change wheel, range change lever, table locks, knee lock, knee crank handle, master isolator, table (X axis) longitudinal traverse handle, saddle lock.
- Functions of the component parts and controls of a vertical milling machine, e.g. quill/spindle, column, range change lever, power feed (traverse), knee crank handle.

What needs to be learned

Learning outcome 3: Understand the types and applications of cutting tools using in turning and milling operations

3A Material properties of cutting tools

- Properties of cutting tool materials, including high speed steel (HSS), tungsten carbide, e.g. hardness, wear resistance, toughness, temperature resistance.

3B Cutting tool profile

- Centre lathe cutting tool profile types and typical applications, including right and left hand facing and turning, knife or side cutting, knurling, light turning and facing, parting/grooving/undercutting, radiusing/forming, roughing, threading/screw cutting, boring bar, twist drill, centre drill, reamer.
- Vertical milling machine cutting tool profile types and typical applications, including arbor, chuck and collet mounted types, face mill, end mill, serrated edge end mill, slot drill, ball-nosed slot drill, dovetail cutter, t-slot cutter, woodruff key cutter, corner rounding cutter, slab mill, side and face cutter, single angle cutter, double angle cutter; concave cutter, convex cutter, corner rounding cutter, involute gear tooth cutter.

3C Rake and clearance of a single point turning tool and a milling cutter

- Function of rake and clearance for a single point turning with consideration of the top (or back) rake angle, side rake angle, front (or end) clearance (or relief) angle, side clearance (or relief) angle, side cutting-edge angle, front (or end) cutting-edge angle.
- Function of rake and clearance of a basic milling cutter with consideration of rake angle, land, primary clearance, secondary clearance.
- Relationship between rake and clearance and cutting tool efficiency.

3D Cutting techniques, their effects and the factors that influence the cutting speed

- Effects of applying roughing, finishing and trial cuts, including minimising production costs, achieving the required dimensional accuracy, achieving the required surface finish, the effects that roughing and finishing cuts have on cutting tool life, surface finish and dimensional accuracy.
- Factors that can influence the rate of material removal, including power and rigidity of the lathe or vertical milling machine and work holding devices, cutting fluid, rigidity of the cutting tool and mount, material properties and rigidity of the workpiece, depth of cut, finish required and tool geometry.

What needs to be learned

3E Method to calculate spindle speeds for turning and vertical milling operations

- Correct spindle speeds for both turning and milling operations, from given cutting speeds using a suitable formula, e.g.

$$N = \frac{1000S}{\pi D}$$

Where N = spindle speed, S = cutting speed in metres per minute and D = diameter of material

Learning outcome 4: Understand quality standards associated with turning and milling operations

4A Types of standards in use

- Requirements of the current standards in use, including British Standards (BS), European Standards (EN), International Standards Organisation (ISO) with consideration to physical standards, international system of units (SI), National Physical Laboratory (NPL), United Kingdom Accreditation Service (UKAS), primary and secondary calibration standards, calibration certificates, standard specifications.
- Reasons for and advantages of implementing quality standards in the manufacture of components, including the elimination of waste and material due to unnecessary production of different patterns and sizes of parts for the same purpose, interchangeability of parts, e.g. ease of servicing and production.

4B Typical engineering terms used in quality standards for turning and vertical milling operations

- Meaning of typical engineering terms used in standards, including surface finish, tolerance, limits of size and fits, classes of fit, including clearance, transition and interference.

4C Surface finish measurement

- Methods of measuring surface finish, including contact, surface roughness comparator plates (visual and tactile), electronic roughness tester (stylus type), non-contact, microscopic inspection, e.g. optical microscope.
- Units of surface finish and their depiction on engineering drawings.

What needs to be learned

Learning outcome 5: Know how to select, mount and use work holding equipment used in turning and milling operations

5A Selecting, mounting, securing and aligning work holding devices

- Types of work holding device:
- for turning – simple work-holding device, e.g. 3-jaw chuck with hard jaws; more complex work holding devices, e.g. 4-jaw chuck with hard jaws, centres (live or dead), faceplate, fixed steady or travelling steady
- for vertical milling – simple work holding device, e.g. machine vice; more complex work holding devices, e.g. clamping direct to machine table, angle plate, vee block and clamps, indexing head/device, rotary table.
- Factors to be considered when selecting a work holding device for turning and vertical milling operations, e.g. shape of component to be held, complexity of turning or milling operation, size of the component to be mounted, material properties of the component requiring turning or vertical milling.
- Select, mount and align suitable work holding devices to a centre lathe and vertical milling machine for given machining requirements.

5B Methods of protecting finished surfaces from marking or damage

- Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.

What needs to be learned
Learning outcome 6: Know how to set up and operate a centre lathe and vertical milling machine
6A Setting up a centre lathe for the manufacture of a component • Operation sequence for the manufacture of a turned component to a given specification. • Centre lathe set up for the manufacture of a turned component, including start and stop, emergency stop. • Quality inspections on a manufactured component to ensure compliance with the given specification. **6B Setting up a vertical milling machine for the manufacture of a component** • Operation sequence for the manufacture of a component to a given specification. • Vertical milling machine set up for the manufacture of a component, including start and stop, emergency stop. • Quality inspections on a manufactured component to ensure compliance with the given specification.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need:

- access to the internet
- relevant engineering standards
- engineering workshops containing centre lathes and vertical milling machines
- appropriate cutting tools and work holding devices.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet to share with their colleagues that includes details of the health and safety implications of operating centre lathes and vertical milling machines within their workplace, or if they are not in employment, within an engineering organisation with which they are familiar. Learners will:

1. describe the duties of employees under current relevant health and safety legislation and regulations for the use of centre lathes and vertical milling machines (AC1.1)
2. describe the safety precautions that must typically be followed when setting up a centre lathe and a vertical milling machine including checks to be carried out before starting the machine, the PPE that must be worn and how to conduct the machine start/stop procedures in both normal and emergency modes. (AC 1.2, 1.3, 1.4)

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce a handout with labelled drawings/photographs for new apprentices that details the parts of a centre lathe and a vertical milling machine. Learners will:

1. describe the function and operation of:

- **four** of each of the main parts of a centre lathe
- **four** of each of the main parts of a vertical milling machine
- **four** controls typically found on a centre lathe
- **four** controls found on a vertical milling machine
  (AC2.1, 2.2)

2. describe **three** types of turning and **three** types of vertical milling operation typically carried out on centre lathes and vertical milling machines. (AC2.3)

Where possible, learners will need to provide clear examples specific to their engineering workplace.

Learning outcome 3

To satisfy the assessment criteria for this learning outcomes learners produce a leaflet to give to new employees detailing the technical aspects of turning and milling. Learners will:

1. give a clear account of at least **three** properties of cutting tool materials (AC 3.1)
2. describe cutting tool profiles used in turning and vertical milling operations. Learners must give a clear account of **two** centre lathe cutting tool profiles types and **two** vertical milling machine cutting tool profile types. (AC3.2)
3. describe the function of the rake and clearance of a single point turning tool and a milling cutter. Learners must give details of the considerations when using these tools (AC3.3)
4. describe cutting techniques used in turning and vertical milling operations. Learners must include details of the effects of using these techniques (AC3.4, 3.5)
5. describe at least **two** factors that influence the selection of particular cutting speeds, feed and depth of cut (AC3.6)
6. state how to calculate the correct spindle speeds required for **two** given turning and **two** given vertical milling operations with examples. (AC3.7)

Where possible, learners will need to provide clear examples specific to their engineering workplace.

Learning outcome 4

To satisfy the assessment criteria for this learning outcome learners produce a leaflet for new apprentices to inform them of the quality standards and associated engineering terms used in turning and vertical milling operations. Learners will:

1. describe the requirements of the current quality standards associated with both turning and vertical milling operations in relation to the engineering workplace. (AC4.1)
2. define the engineering terms used in the quality standards associated with turning and vertical milling operations (AC4.2)
3. describe **three** methods of measuring surface finish for turning and vertical milling operations giving suitable examples of surface finish measurement used in the engineering workplace. (AC4.3)
4. describe the **two** advantages of manufacturing components to recognised engineering standards (AC4.4)

Where possible, learners will need to provide clear examples specific to their engineering workplace.

Learning outcome 5 and 6

To satisfy the assessment criteria for these learning outcomes, learners relate their evidence to two given turning operations. They will refer to a completed log book which includes photographic evidence and quality inspection records of practical activities they have undertaken to demonstrate their knowledge of using centre lathes and vertical milling machines. Where possible, learners undertake these activities within their own workplace, or if they are not in employment, in a realistic work environment. Learners **will**:

1 identify appropriate work holding devices for two different given turning operations with **one** being **straightforward** and **one** being more **complex** (AC5.1)

2. describe how to safely mount the work holding devices, and state appropriate surface protection techniques (AC5.2, 5.3)
3. describe how to safely conduct the turning and milling operations including setting up and using a centre lathe and vertical milling machine to manufacture components (AC6.1, 6.2)
4. describe how to use appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements. (AC6.3)

Unit 6: Grinding Techniques

Level: 2

Unit type: Optional

Assessment type: Internal

Guided learning hours: 50

Unit introduction

Engineers use a variety of machinery during the manufacture of finished products. By carrying out grinding operations, engineers can produce parts with close tolerances and fine surface finishes but the machinery they use can be dangerous to operate. It is, therefore, important to know how to use the machinery correctly, using job instructions, manufacturers' guidelines and organisational procedures, so that the end product is produced safely and efficiently to the appropriate quality standard.

In this unit, you will learn about how to operate these machines safely while complying with relevant legal requirements and current quality standards. You will explore how grinding machines operate and the types of abrasive wheels and work holding devices that can be used. You will then be able to apply your knowledge when carrying out practical activities safely to produce ground components that comply with appropriate engineering standards.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand how to use grinding machines safely	1.1	Describe the health and safety requirements associated with grinding operations
		1.2	Describe the specific safety precautions relating to the setting and use of a surface grinding machine
		1.3	Describe how to conduct pre-use checks on the abrasive wheel
		1.4	Describe machine start/stop procedures in both normal and emergency mode.
2	Know the functions of the tooling and equipment used in grinding operations	2.1	Describe the functions of the component parts of typical surface grinding machines
		2.2	Describe the operation of the controls of typical surface grinding machines
		2.3	Describe the types of working devices that can be used in surface grinding operations
		2.4	Describe the types of operations that can be carried out on a surface grinding machine
3	Know how to select, mount and use work holding equipment for grinding operations	3.1	Identify appropriate work holding devices for grinding operations
		3.2	Describe how to mount and align work holding devices for grinding operations
		3.3	Describe standard methods of protecting finished surfaces from marking or damage during the grinding operation

Learning outcomes		Assessment criteria	
4	Understand the types and applications of abrasive wheels used in grinding operations	4.1	Define abrasive wheel terms used in grinding operations
		4.2	Describe the types and construction of abrasive wheels, materials and properties
		4.3	Explain the reasons for balancing abrasive wheels
		4.4	Describe the correct procedure for balancing an abrasive wheel
		4.5	Describe cutting techniques used in grinding operations
		4.6	Explain the effects of different cuts on the quality of the finished product, production costs and tool life
		4.7	Explain the effects of peripheral speed, table feed, table speed and cutting speed on cutting efficiency and surface finish
5	Understand quality standards associated with grinding operations	5.1	Outline the current quality standards associated with grinding operations
		5.2	Define the engineering terms used in quality standards associated with grinding operations
		5.3	Describe methods of measuring surface finish for grinding operations
		5.4	Outline the advantages of manufacturing components to recognised engineering standards
6	Know how to set up and operate a surface grinding machine	6.1	Describe how to set up a grinding machine to manufacture a ground component
		6.2	Describe how to use a grinding machine to manufacture a ground component
		6.3	State appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the grinding operation

Unit content

What needs to be learned
Learning outcome 1: Understand how to use grinding machines safely
1A Health and safety requirements associated with grinding operations • Duties of employees under relevant legislation, with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances. • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of a surface grinding machine** • The specific safety precautions relating to the setting and use of a surface grinding machine, including checking the abrasive wheel is in a safe condition before starting the machine, ensuring that the workpiece is secure and grinding wheels are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping the surface grinding machine under normal conditions and in an emergency. • Identification of trapping hazards, e.g. between the table and saddle. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of dust extraction equipment. • Use of PPE to include safety glasses, apron/overalls, ear protection.

What needs to be learned

Learning outcome 2: Know the functions of the tooling and equipment used in grinding operations

2A Functions of the component parts of surface grinding machines

- Component parts, including the base, column, wheel head, saddle, table, handwheels, cross traverse, table traverse, wheel guard, splash guard.
- Functions, e.g. column handwheel, cross traverse, table traverse.

2B Functions and operation of the controls of surface grinding machines

- Controls found on surface grinding machines, including trip dogs, reversing valve lever, table speed control, cross feed selector, incremental feed rate control, continuous feed rate control, extractor and coolant system, control panel.
- Explanation of the operation of controls of surface grinding machines, e.g. trip dogs, reversing valve lever, table-speed control knob, cross feed selector.

2C Types of work holding devices

- Work holding devices that can be used in surface grinding operations, including magnetic chuck or blocks, precision grinding vice, angle plates, vee blocks and clamps, vee block indexing fixture, e.g. Harig Grind-All.

2D Types of operation that can be carried out on a surface grinding machine

- Engineering applications of surface grinding machines, including flat, parallel and square faces, vertical and angular faces, steps and shoulders, slots, profile forms.

What needs to be learned
Learning outcome 3: Know how to select, mount and use work holding equipment for grinding operations
3A Selecting, mounting and aligning work holding devices • Factors to be considered when selecting a work holding device for grinding operations, e.g. shape of component to be ground, complexity of grinding operation, size of the component to be mounted, material properties of the component requiring grinding. • Select, safely mount and align suitable work holding devices to a surface grinding machine for given grinding requirements. **3B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.

What needs to be learned

Learning outcome 4: Understand the types and applications of abrasive wheels used within engineering

4A Types and construction of abrasive wheels, materials and properties

- Types of abrasive wheels most commonly used on a surface grinder, including types 1, 5 and 7, wheel identification markings.
- Types of material used to manufacture abrasive wheels, their mechanical properties and uses, including aluminium oxide and silicon carbide, typical grain/grit sizes, e.g. coarse, medium, fine, very fine, designation of bonding agent strength and density of grain particles.
- Importance of choosing the correct wheel grit and bonding strength for cutting efficiency and the material being cut.

4B Reasons for balancing abrasive wheels

- The importance of balancing abrasive wheels (on initial use and at frequent intervals thereafter), including the prevention of damage to the workpiece, the prevention of damage/wear to the machine spindle bearings, catastrophic failure of the wheel.
- Balancing an abrasive wheel, including truing the wheel safely before balancing and re-truing afterwards, the use of a grinding wheel balancing stand, sensitive bubble level, mandrel, wheel mount flanges and balancing weights; how to identify the heaviest part of wheel assembly and how to adjust the balancing weights until the assembly remains stationary in any position.

4C Cutting techniques and their effects

- The effects of applying roughing, finishing and trial cuts, including minimising production costs, achieving the required dimensional accuracy, achieving the required surface finish, the effects that roughing and finishing cuts have on wheel life, surface finish and dimensional accuracy.

4D Abrasive wheel terminology

- Definitions of typical abrasive wheel terms used to include peripheral speed (maximum and recommended) table feed, maximum allowable speed, table speed, cutting depth.
- Effects of peripheral speed, table feed, table speed and cutting speed on cutting efficiency and surface finish.

What needs to be learned

Learning outcome 5: Understand quality standards associated with grinding operations

5A Types of standards in use

- Requirements of the current standards in use, including including British Standards (BS), European Engineering Standards (EN), International Organisation for Standardization Standards (ISO) with consideration to physical standards, international system of units (SI), National Physical Laboratory (NPL), United Kingdom Accreditation Service (UKAS), primary and secondary calibration standards, calibration certificates, standard specifications.
- Reasons for and advantages of implementing quality standards in the manufacture of components, including the elimination of waste and material due to unnecessary production of different patterns and sizes of parts for the same purpose, interchangeability of parts, e.g. ease of servicing and production.

5B Typical engineering terms used in quality standards for grinding operations

- Meaning of typical engineering terms used in standards, including tolerance, limits of size, limits and fits, classes of fit including clearance, transition and interference.

5C Surface finish measurements

- Methods of measuring surface finish, including contact, surface roughness comparator plates (visual and tactile), electronic roughness tester (stylus type), non-contact, microscopic inspection, e.g. optical microscope.
- Units of surface finish and their depiction on engineering drawings.

What needs to be learned
Learning outcome 6: Know how to set up and operate a surface grinding machine
6A Component parts and controls of a surface grinding machine • Safe use of the component parts and controls of a surface grinding machine. • Component parts, including base, column, wheel head, saddle, table, handwheels, cross traverse, table traverse, wheel guard, splash guard, work holding device. • Controls, including trip dogs, reversing valve lever, feed controls, speed controls, start/stop buttons, emergency stop buttons, main isolators. **6B Setting up a grinding machine for the manufacture of a ground component** • Prepare an operation sequence for the manufacture of a given ground component. • Set up a grinding machine for the manufacture of a ground component. • Start and stop a surface grinding machine and carry out an emergency stop. • Manufacture a ground component to a given specification. • Carry out quality inspections on a manufactured component to ensure compliance with the given specification.

Essential information for tutors and assessors

Essential resources

For this unit, centres need relevant engineering standards and engineering workshops with surface grinding machinery.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a handout to share with their colleagues that details the health and safety implications of operating grinding equipment within their own workplace, or if they are not in employment, within an engineering organisation with which they are familiar.

Learners will:

1. describe the health and safety requirements for the use of abrasive wheels including the duties of employees under current relevant legislation and environmental requirements (AC1.1)
2. describe the safety precautions that must typically be followed when setting up a surface grinding machine including the use of PPE and how to conduct pre-use checks on the abrasive wheel and machine start/stop procedures in both normal and emergency modes. (AC1.2, 1.3, 1.4)

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet to share with their colleagues that details the parts of a surface grinding machine. Learners will:

1. describe the function of **four** of the main component parts of a surface grinding machine. (AC2.1)
2. describe the function and operation of **four** controls typically found on a surface grinding machine. (AC2.2)
3. describe **three** types of work holding device that can be used for grinding operations giving for each **one** example of their use. (AC2.3)
4. describe **three** types of grinding operation typically carried out on a surface grinding machine (AC2.4)

Where possible, learners will need to provide clear examples specific to their own workplace.

Learning outcomes 3 and 6

To satisfy the assessment criteria for these learning outcomes, learners relate their evidence to two given grinding operations. Learners will refer to evidence from practical activities they have undertaken including a completed log book (including photographic evidence) and quality inspection records to demonstrate their knowledge of grinding operations. Where possible, learners undertake these activities within their own workplace, or if they are not in employment, in a realistic work environment. Learners will:

1. identify appropriate work holding devices for two different given grinding operations with **one** being **straightforward** and **one** being more **complex**. (AC3.1)
2. describe how to safely mount the work holding devices, giving details of surface protection techniques (AC3.2)
3. describe how to safely conduct the surface grinding operations and use appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements. (AC3.3)
4. describe how to safely conduct the surface grinding operations including setting up and using a grinding machine to manufacture components (AC6.1, 6.2)
5. state appropriate inspection techniques to ensure compliance with relevant standards for the grinding operation. (AC6.3)

Where possible, learners will need to provide clear examples specific to their own workplace.

Learning outcome 4

To satisfy the assessment criteria for this learning outcome learners produce a leaflet to give to new employees detailing the technical aspects of abrasive wheels Learners will:

1. define **three** abrasive wheel terms used in grinding operations including peripheral speed (maximum and recommended), and two from table speed, maximum allowable speed, table speed, cutting depth (AC4.1)
2. describe the types and construction of abrasive wheels that are typically used within their own engineering organisation giving technical details such as grit size, density and usage (AC4.2)
3. explain **three** reasons for ensuring abrasive wheels are balanced and describe the procedures that need to be followed to balance an abrasive wheel. (AC4.3, 4.4)
4. describe the cutting techniques undertaken during grinding operations and explain the effects that varying these cuts have on the quality of the components produced. (AC4.5, 4.6)
5. explain the effects of peripheral speed, table feed, table speed and cutting speed on cutting efficiency and surface finish, with relevant examples for each. (AC4.7)

Where possible, learners will need to provide clear examples specific to their own workplace.

Learning outcome 5

To satisfy the assessment criteria for this learning outcome learners produce a leaflet for new apprentices to inform them of the quality standards and associated engineering terms used in grinding operations. Learners will:

1. provide an overview of **two** current quality standards associated with grinding operations giving an outline of their key requirements (AC5.1)
2. define engineering terms used in quality standards associated with grinding operations (AC5.2)
3. describe **three** methods of measuring surface finish during grinding operations (AC5.3)
4. outline **three** benefits to engineering organisations that using recognised engineering standards to manufacture products bring to the company (AC5.4)

Where possible, learners will need to provide clear examples specific to their own workplace.

Unit 7: Principles of Computer Numerical Control (CNC) Milling and Turning

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**80**

Unit introduction

The demand for high-quality machined components with low lead times has pushed engineers to automate traditional engineering machinery such as centre lathes and milling machines. These computer numerical control (CNC) machines are complex to operate and machine operators need to have skills that may not traditionally be thought of as 'engineering'. For example, who would have thought manufacturing engineers would have to be proficient in computer programming?

In this unit, you will learn about how to operate CNC machines safely while complying with relevant legal requirements and current quality standards. You will explore how CNC lathes and milling machines operate and the types of cutting tools and work holding devices that can be used. You will also learn how to produce computer programs which can be used to produce components that comply with appropriate engineering standards.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the equipment, procedures and relevant safety precautions used in CNC milling and turning operations	1.1	Describe the health and safety requirements associated with CNC turning and milling operations
		1.2	Describe the safety precautions relating to the setting and use of a CNC lathe and milling machine
		1.3	Describe CNC lathe and milling machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in CNC milling and turning operations	2.1	Describe the functions and operation of the component parts and controls of typical CNC lathes
		2.2	Describe the functions and operation of the component parts and controls of typical CNC milling machines
		2.3	Describe the types of turning and milling operations that can be carried out on a CNC lathe and milling machine
		2.4	Describe types of work holding device that can be used for both CNC turning and CNC milling operations

Learning outcomes		Assessment criteria	
3	Understand the types and applications of cutting tools used in CNC milling and turning operations	3.1	Describe the properties of cutting tool materials used in CNC milling and turning operations
		3.2	Explain the factors that influence cutting tool selection for CNC milling and turning operations
		3.3	Describe cutting tool profiles used in CNC milling and turning operations
		3.4	Describe the function of the rake and clearance of a CNC single point turning tool and a milling cutter
		3.5	Describe cutting techniques used in CNC turning and milling operations
		3.6	Explain the effects of different cuts on the quality of the finished product, production costs and tool life
		3.7	Explain the factors that influence the selection of particular cutting speeds, feed and depths of cut when conducting turning and milling operations
		3.8	State how to determine correct CNC machine running parameters for turning and milling operations
		3.9	Describe the types of cutting fluids that can be used in milling and turning operations
		3.10	Describe the effects that cutting fluid has on milling and turning operations
4	Understand basic CNC milling and turning operations and programming	4.1	Define the term 'computer numerical control'
		4.2	Describe the benefits of CNC control over conventional milling and turning techniques
		4.3	Define the term 'part program' and associated basic part programming terminology
		4.4	Describe the methods of inputting data into CNC controller
		4.5	Describe how to prepare a basic part program
		4.6	Describe the methods used to prove a part program
		4.7	Explain the reasons for proving a part program
		4.8	Describe how to deal with program errors

Learning outcomes		Assessment criteria	
5	Understand quality standards associated with CNC milling and turning operations	5.1	Describe methods of measuring surface finish for turning and milling operations
		5.2	Outline the current quality standards associated with turning and milling operations
		5.3	Define the engineering terms used in quality standards associated with turning and milling operations
6	Know how to select, mount and use work holding equipment used in CNC milling and turning operations	6.1	Identify appropriate work holding devices for turning and milling operations
		6.2	Describe how to mount, secure and align work holding devices for turning and milling operations
		6.3	State standard methods of protecting finished surfaces from marking or damage during turning and milling operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment, procedures and relevant safety precautions used in CNC milling and turning operations
1A Health and safety requirements associated with CNC milling and turning operations • Duties of employees under relevant current legislation with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of CNC machines** • Safety precautions relating to the setting and use of a CNC lathe and milling machine, including checking and ensuring that the workpiece is secure and that cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping a CNC machine under normal conditions and in an emergency. • Fitting and adjustment of machine guarding and interlocks. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant, use of PPE to include safety glasses.

What needs to be learned

Learning outcome 2: Understand the function of the tooling and equipment used in CNC milling and turning operations

2A Functions and operation of the component parts and controls of CNC lathes

- CNC lathe parts and controls: component parts and controls of a CNC lathe, including start/stop controls, tool turret, saddle, bed/slant bed, headstock, spindle, cross slide, tailstock, servo motors, controller, emergency stop, base, coolant pump, fully enclosed interlocking guarding.
- Functions of the component parts and controls of a CNC lathe, e.g. the tailstock, tool turret, saddle, headstock.

2B Functions and operation of the component parts and controls of CNC milling machines

- CNC milling machine parts and controls: component parts and controls of a CNC milling machine, including start/stop controls, emergency stop, guards, motor, head, power/automated drawbar, machine spindle, tool carousel, column, table, saddle, slideways, bed, fully enclosed interlocking guarding, servo motors, controller, coolant pump.
- Functions of the component parts and controls of a CNC milling machine, e.g. start/stop controls, tool carousel, saddle, machine spindle, guards.

2C Types of operation that can be carried out on a CNC lathe and CNC milling machines

- CNC lathe operations, including plain, parallel, stepped, tapered and eccentric diameters, flat faces, internal and external profiles, internal and external screw threads, drilled holes, tapped, bored and reamed holes, chamfers, radii, undercuts and parting off.
- CNC milling machine operations, including flat, parallel and square faces, open ended and enclosed slots/ recesses and pockets, steps/shoulders, angular faces, drilled, reamed and tapped holes (linear and circular pitched), bored holes, indexed and rotated forms, internal/concave and external/convex profiles, special forms, such as gear forms and serrations.

What needs to be learned

Learning outcome 3: Understand the types and applications of cutting tools used in CNC milling and turning operations

3A Selection and properties of cutting tools

- Properties of cutting tool materials, including Tungsten carbide, ceramic and diamond indexable tipped tooling, e.g. hardness, wear resistance, toughness, temperature resistance.
- Factors that determine cutting tool selection and use, such as condition of material supplied, hardness of the material, tolerances to be achieved, component surface finish and specifications.

3B Cutting tool profile

- CNC lathe cutting tool profile types and typical applications, including roughing tool, finishing tool, parting-off tool, screw thread tool, profiling tools, form tools, centre drills, twist/core drills, boring tools, reamers, maxi-tipped drills, carbide insert drills.
- CNC milling machine cutting tool profile types and typical applications, including arbor, chuck and collet mounted types (as applicable), face mill, end mill, serrated edge end mill, slot drill, ball-nosed cutters, dovetail cutter, t-slot cutter, woodruff key cutter, corner rounding cutter, boring tool, fly cutter, twist drill, centre drill and reamer, special profile cutters.

3C Rake and clearance of CNC milling and turning tools

- Rake and clearance of a CNC single point turning tool functions with consideration to the top (or back) rake angle, side rake angle, front (or end) clearance (or relief) angle, side clearance (or relief) angle, side cutting-edge angle, front (or end) cutting-edge angle.
- Rake and clearance of a milling cutter and its functions with consideration to rake angle, land, primary clearance, secondary clearance.
- Functions of tool rake and clearance angles within consideration to effective cutting, influence on chip formation, positive and negative rake, prevention of rubbing, how rake and clearance angles may vary, including cutting tool type, cutting tool material and the material being cut.

What needs to be learned

3D Cutting techniques, their effects and the factors that influence the cutting speed

- Effects of applying roughing, finishing and trial cuts, including minimising production costs, achieving the required dimensional accuracy, achieving the required surface finish, the effects that roughing and finishing cuts have on cutting tool life, surface finish and dimensional accuracy.
- Factors that can influence the rate of material removal, including power and rigidity of the lathe or milling machine and work holding devices, cutting fluid, rigidity of the cutting tool and mount, material properties and rigidity of the workpiece, depth of cut, finish required and tool geometry.

3E Determine correct CNC machine running parameters for turning and milling operations

- Calculation of correct spindle speeds for CNC turning and milling operations, from given cutting speeds using a suitable formula, e.g.

$$N = \frac{1000S}{\pi D}$$

  Where S = cutting speed in metres per minute and D = diameter

- Determination of correct cutting speeds and feed rates for CNC turning and milling operations using cutting tool manufacturer's data tables.

3F Cutting fluids, types and their effects on milling and turning operations

- Types of cutting fluids their properties and use, including neat cutting oils, soluble oils, synthetic fluids, semi-synthetic fluids, vegetable oils.
- Effects of using cutting fluids in turning and milling operations, including cooling and lubrication of the workpiece, chip and cutting tool, reduction in chip welds forming on the edge of high-speed steel (HSS) tools, improved surface finish, swarf removal, corrosion prevention of the workpiece and CNC machine.

What needs to be learned

Learning outcome 4: Understand basic CNC milling and turning operations and programming

4A What is meant by the term 'computer numerical control'?

- Definition of computer numerical control (CNC).

4B Benefits of CNC milling and turning operations'

- Benefits of CNC milling and turning compared to conventional milling and turning methods, including high productivity rates, uniformity of product, reduced component rejection, reduced tooling costs, less operator involvement, complex shapes machined more easily.

4C Part program and associated terminology

- Definition of the term 'part program' and associated terminology, including computer coding language, including G-code and M-code, used in CNC programs, machine axis identification, positional information, machine management, tool offsets and basic auxiliary/miscellaneous functions, datums, absolute and relative positioning.

4D Preparing a part program, proving and loading into a CNC machine

- Preparation of a part program, including planning requirements such as analysis of the working drawing, preparing a work plan, set up, including material, tooling and work holding, writing a part program.
- Methods of loading a part program into a CNC controller, including manual data input (MDI), storage/transfer from media such as disk, CD ROM, USB flash drive or portable external hard drive, Direct Numerical Control (DNC) such as RS 232 link, wireless or wired network (ethernet).
- Methods of proving a part program, including single block run, dry run, simulation of feed and speed override controls.
- Reasons for proving a part program, e.g. checking for errors in the code, ensuring tool changes occur correctly.
- Dealing with error codes before making the first cut.

What needs to be learned
Learning outcome 5: Understand quality standards associated with CNC milling and turning operations
5A Surface finish measurements • Methods of measuring surface finish, including contact, surface roughness comparator plates (visual and tactile), electronic roughness tester (stylus type), non-contact, microscopic Inspection, e.g. optical microscope. • Units of surface finish and their depiction on engineering drawings. **5B Types of quality standards in use** • Requirements of the current standards in use, including British Standards (BS), European Standards (EN), International Standards Organisation (ISO) with consideration to physical standards, international system of units (SI), National Physical Laboratory (NPL), United Kingdom Accreditation Service (UKAS), primary and secondary calibration standards, calibration certificates, standard specifications. • Definition of engineering terms used in quality standards for CNC turning and milling operations: definitions; to include tolerance, limits of size, limits and fits, classes of fit, including clearance, transition and interference.
Learning outcome 6: Know how to select, mount and use work holding equipment used in CNC milling and turning operations
6A Selecting, mounting, securing and aligning work holding devices • Factors to be considered for CNC milling and turning operations, e.g. shape of component to be held, complexity of the milling or turning operation, size of the component to be mounted, material properties of the component requiring milling or turning. • Select, safely mount and align suitable work holding devices to a CNC lathe and CNC milling machine for given milling and turning requirements. **6B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.

Essential information for tutors and assessors

Essential resources

For this unit, centres need:

- relevant engineering standards
- tool manufacturers' data tables
- engineering workshops containing CNC lathes, milling machines and associated cutting tools and work holding devices.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an information to share with their colleagues that details the health and safety implications of operating CNC lathes and milling machines within their own organisation, or if they are not in employment, within an engineering organisation with which they are familiar. Learners will:

1. describe the health and safety requirements associated with CNC turning and milling operations including duties of employees under current relevant legislation and environmental considerations. (AC1.1)
2. describe the safety precautions that must typically be followed when setting up CNC lathes and milling machines including the checks to be carried out before starting the machine, the PPE which must be worn and how to conduct the machine start/stop procedures in both normal and emergency modes. (AC1.2, 1.3)

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce a handout containing labelled diagrams for new apprentices that details the parts of a CNC lathe and a milling machine. Learners will:

1. describe the functions of **four o**f the main parts of a CNC lathe and four main parts of a CNC milling machine by annotating a drawing/photograph provided by the tutor (AC2.1)
2. describe the function and operation of **four** controls of a CNC lathe and four parts of a CNC milling machine (AC2.2)
3. describe **three** types of turning and milling operation typically carried out on CNC lathes and milling machines (AC2.3)
4. describe **three** types of work holding device that can be used for CNC turning and three work holding devices that can be used for CNC milling operations giving typical examples of their use (AC2.4)

Learning outcome 3

To satisfy the assessment criteria for this learning outcome learners produce a leaflet to give to new employees detailing the technical aspects of CNC turning and milling. Learners will:

1. describe the properties of cutting tool materials used in CNC milling and turning operations including Tungsten carbide, ceramic and diamond indexable tipped tooling. (AC3.1)
2. explain **four** factors that can influence the selection of cutting tools during CNC turning and milling operations with **one** reason for each factor (AC3.2)
3. describe cutting tool profiles used in CNC milling and turning operations. Learners must include details of **four** cutting tools and their profiles. (AC3.3)
4. describe the function of the rake and clearance of a CNC single point turning tool and a milling cutter. Learners must give details of the considerations when using these tools (AC3.4).
5. describe cutting techniques used in CNC milling operations. Learners must include details of the effects of using these techniques (AC3.5, 3.6).
6. explain at least **two** factors that influence the selection of particular cutting speeds, feed and depth of cut when conducting turning and milling operations with **one** reason for each factor (AC3.7)
7. state how to calculate the correct spindle speeds for given cutting speeds for **two** CNC turning and **two** CNC milling operations, using appropriate formulae. (AC3.8)
8. describe **three** types of cutting fluids that can be used during CNC milling and turning operations and the effects that cutting fluids have on cutting operations. (AC3.9, 3.10)

Learning outcome 4

To satisfy the assessment criteria for this learning outcome learners produce a leaflet to give to new employees with details of CNC milling and turning principles and terminology. Learners will:

1. give the meaning of the term 'computer numerical control' using correct terminology (AC4.1)
2. describe **four** benefits of CNC milling and turning over conventional milling and turning techniques (AC4.2)
3. state what is meant by the term 'part program' and **four** associated basic part programming terms (AC4.3)
4. describe **three** methods of inputting data into a CNC controller. (AC4.4)
5. describe how to prepare a basic part program, including details of all stages (AC4.5)
6. give a clear account of **four** methods used to prove a part program, and give **two** reasons for proving a part program. Learners must then describe how to deal with program errors (AC4.6, 4.7, 4.8)

Learning outcome 5

To satisfy the assessment criteria for this learning outcome learners produce a leaflet for new apprentices to inform them of the quality standards and associated engineering terms used in turning and milling operations. Learners will:

1. describe **three** methods of measuring surface finish for CNC turning and CNC milling operations. (AC5.1)
2. give an overview of the requirements of the current quality standards associated with CNC turning and CNC milling operations (AC5.2)
3. give the meaning of the engineering terms used in quality standards associated with CNC turning and CNC milling operations (AC5.3)

Learning outcome 6

To satisfy the assessment criteria for this learning outcome, learners relate their evidence to two given CNC turning operations. Learners will refer to evidence from practical activities they have undertaken including a completed log book (including photographic evidence) and quality inspection records to demonstrate their knowledge of grinding operations. Where possible, learners undertake these activities within their own workplace, or if they are not in employment, in a realistic work environment. Learners will:

1. identify appropriate work holding devices for two different given CNC turning operations with **one** operation being **straightforward** and **one** being more **complex**. (AC6.1)
2. identify work holding devices for two different given CNC milling operations with **one operation** being **straightforward** and **one** being more **complex**. (AC6.1)
3. describe how to safely mount the work holding devices, demonstrating surface protection techniques as appropriate (AC6.2)
4. describe **two** methods of protecting finished surfaces from marking or damage during CNC milling operations. (AC6.3)

Unit 8: Computer Aided Design

Level: 2

Unit type: Optional

Assessment type: Internal

Guided learning hours: 90

Unit introduction

Computers and bespoke software are used for a wide range of applications in engineering. They can be used for simulation, stress analysis, computer aided manufacture (CAM) and computer aided design (CAD).

In this unit, you will learn how to set up a CAD system and use the software to produce a range of engineering drawings. You will learn how to use national and international standards to ensure that, wherever the drawings produced will be viewed, they will be clearly understood. You will learn about the appropriate health and safety requirements and investigate some of the more advanced features of the software, ensuring that you comply with industry standard practice.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the risks to health and safety associated with the use of computer equipment and associated peripheral devices	1.1	Describe the health and safety hazards associated with the use of visual display units and associated peripheral devices
		1.2	State the key features of the Health and Safety at Work etc. Act 1974 (HASAW Act)
		1.3	Outline the key features of the Health and Safety (Display Screen Equipment) Regulations
		1.4	Describe the environmental conditions required for safe visual display unit (VDU) operation
		1.5	Outline the responsibilities of both the employer and employee in ensuring safe use of computer equipment and associated peripheral devices
2	Understand how to configure the CAD system to suit drawing requirements	2.1	Describe the types of CAD drawing parameters that can be configured to the drawing requirements
		2.2	Describe the benefits and limitations of using CAD systems to produce engineering drawings
3	Understand the need to comply with national and international drawing standards	3.1	Explain the requirement for drawing standards in a modern engineering environment
		3.2	Recognise the types of features and symbols used in national and international drawing standards

Learning outcomes		Assessment criteria	
4	Understand how to use CAD software for the production of 2D and 3D industry standard engineering drawings	4.1	Describe the requirements and key features of CAD software in the production of 2D engineering drawings
		4.2	Describe the typical features used in the production of 2D drawings
		4.3	Describe the typical drawing features used in the development of 3D models
		4.4	Describe the key features of CAD software in the production of 3D models
5	Understand how to use layers, copy, modify and manipulate drawn entities to maintain drawing efficiency	5.1	Explain the requirement for using layers to enable drawing efficiency
		5.2	Describe the types of drawing commands typically used to manipulate drawings using CAD
6	Know how to produce 2D and 3D industry standard engineering drawings	6.1	Describe how to produce a 2D CAD assembly drawing from parts drawings
		6.2	Describe how to produce fully dimensioned 2D CAD parts drawings to basic and further CAD commands and BS conventions
		6.3	Describe how to produce a 3D CAD model from a 2D CAD assembly drawing

What needs to be learned

Learning outcome 1: Understand the risks to health and safety associated with the use of computer equipment and associated peripheral devices

1A Health and safety hazards associated with the use of visual display units and associated peripheral devices

- Electrical hazards associated with working with visual displays units (VDU) and their associated peripheral devices, e.g. printers, plotters.
- Hazards to health associated with performing repetitive tasks, e.g. backache, repetitive strain injury.
- Hazards to health associated with VDU screen glare and excessive VDU use, e.g. eye strain, fatigue.

1B Health and safety requirements associated with operating visual display units and associated peripheral devices

- Health and Safety at Work etc. Act 1974, including, scope, employer responsibilities, e.g. risk assessment, training/ instruction of staff, protection of employees from risk and employee responsibilities, e.g. take reasonable care of own health and safety and that of others, not to interfere with or misuse anything that's been provided for your health, safety or welfare, report any injuries or illnesses suffered as a result of the job.
- Health and Safety (Display Screen Equipment) Regulations, including scope, requirements and responsibilities (who is covered/at risk, training, risk assessment, equipment safety checks).
- Operator requirements when working with VDUs, e.g. working position, lighting, environment.

Learning outcome 2: Understand how to configure the CAD system to suit drawing requirements

2A CAD configurable drawing parameters

- Drawing parameters that can be configured within CAD systems, including drawing templates, sheet sizes, drawing lines, limits and types, scales, text and dimension styles, screen display, layers, units, toolbars, drawing origin and datum, peripheral devices.

2B Benefits and limitations

- Benefits associated with CAD systems, e.g. productivity and speed of drawing creation, uniformity of production, standardised parts, symbols etc., electronic data exchange and transfer, computer aided manufacture (CAM).

What needs to be learned
Learning outcome 3: Understand the need to comply with national and international drawing standards
3A Requirement for drawing standards • Commonality of drawing interpretation. • Removal of language barriers – use of symbology. • Global manufacture of component parts assembled in one location. **3B Features and symbols** • Use of 1st and 3rd angle projection. • Features used in engineering drawings, e.g. symbols, lettering and numbering, line types, dimensioning. • Units of measurement, e.g. metric, imperial, angular. • Symbols utilised in engineering drawings, e.g. welding, electrical/electronic, mechanical, fluid power.

What needs to be learned

Learning outcome 4: Understand how to use CAD software for the production of 2D and 3D industry standard engineering drawings

4A Software requirements and key features

- Reference point.
- Ease of use.
- Software and hardware compatibility.
- Coordinate input methods, e.g. absolute, relative/incremental, polar.
- Drawing aids, e.g. coordinate grids and snaps, object snaps, viewing features, e.g. zoom, previous, pan.

4B Drawing features

- Geometry, e.g. lines, circles, arcs, ellipses.
- Dimensioning, including linear dimensions, radial dimensions, angular dimensions, leaders' dimensions, text dimensions, tolerances dimensions.
- Text, including text location, font type, size and orientation.

4C Drawing features of 3D CAD models

- 3D features of engineering components, including: threads – male and female, holes – plain, drilled, threads, countersunk, fillet, chamfer, combination of solid objects, including Boolean operations.
- Placing 3D components, including degrees of freedom, XYZ translational freedom and XYZ rotational freedom.
- Assembly constraints and the relationships between components, including mate constraint and angle constraint assembly relationships, insert constraint and tangent constraint assembly relationships.
- Modification to 3D components due to assembly constraints.
- Consideration of assembly, including storyboarding, component relationship.
- Use of rendering, including render, shadows, reflections, lights, materials, textures, ray tracing.

4C Key features of 3D CAD software

- Configuration of the parametric modeller, including origin, units, snap and grid, correct format, project files, selection of file types, and planes, e.g. XY, XZ and YZ.
- Use of display commands, including pan, zoom, and orbit.

What needs to be learned

Learning outcome 5: Understand how to use layers, copy, modify and manipulate drawn entities to maintain drawing efficiency

5A Layers

- Importance of the use of layers in CAD.
- Definition of a layer.
- Requirements of efficient layer management.

5B Drawing manipulation

- Typical drawing manipulation commands, including scaling, mirroring, rotating, trimming, moving/translating, corner filleting/chamfering, exploding, copying, arrays/patterns, extending, stretching, erasing.

Learning outcome 6: Know how to produce 2D and 3D industry standard engineering drawings

6A 2D CAD components parts drawings and assembly drawings

- Basic and advanced features of a CAD system (drawings of component parts that form an assembly drawing to BS8888, including:
  - basic drawing commands and editing commands to produce and erase lines, circles, text
  - outputting to a printer/plotter device
  - appropriate tools to allow accurate geometry definition
  - manipulation of views, including zoom and pan options
  - saving the drawing data in an appropriate format.
- Modification and manipulation of drawn features, including scaling, revolving/rotating, copying/duplicating and moving.
- Dimensioning and hatching.
- Drawing template, typically to include a border, title block, projection, scale, drawing number, title of drawing, material, names of drawing creator and who checks/authorises the drawing.
- Further CAD commands, including erase, stretch, trim, scale; absolute, relative and polar coordinates, features, e.g. type of line, grid, snap, circle, text, hatch, zoom-in, zoom-out.

6B 3D CAD model using a 2D CAD assembly drawing

- 3D modelling features of a CAD system: 3D model of an assembly, including: configuration of the parametric modeller, including origin, units, snap and grid, correct format, project files, selection of planes, e.g. XY, XZ and YZ, use of display commands, including pan, zoom, and orbit.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need:

- computers equipped with appropriate peripherals and installed with CAD software
- relevant standards and manufacturers' information
- a learning centre/library.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet to share with new apprentices that covers the hazards to health that are associated with the use of visual display screens. Learners will:

1. use appropriate technical language to describe the hazards to health that are present when operating visual display units. Learners must include details of the **three** types of hazard. (AC1.1)
2. state the requirements of the HASAW Act and Health and Safety (Visual Display Equipment) regulations in relation to protecting the workforce when using VDUs (AC1.2)
3. briefly describe the key features of the Health and Safety (Display Screen Equipment Regulations (AC1.3)

4. describe the local environmental considerations such as adequate lighting, heating/ventilation that need to be considered when operating VDUs. (AC1.4)
5. give an overview of employer and employee responsibilities in ensuring safe use of computer equipment and peripheral devices specific to the engineering workplace. (AC1.5)

Learning outcome 2 and 3

To satisfy the assessment criteria for these learning outcomes, learners produce an information sheet to share with CAD technicians new to their engineering organisation. Learners will:

1. describe the drawing parameters that can be set by the user during system configuration, making use of annotated screen shots or embedded video clips; at least **five** drawing parameters should be covered. (AC2.1)
2. give a clear account of **four** benefits and **four** limitations of the use of CAD software in comparison to conventional drawing techniques (AC2.2)
3. give **three** reasons for using drawing standards in a multi-national engineering company with locations in different parts of the world (AC3.1)
4. recognise features and symbols used in national and international drawing standards, from given drawings provided by the tutor (AC3.2)

CAD drawings produced by the learner can be used to support all of the above. The drawings could be added to a portfolio of evidence, with appropriate cross-referencing.

Where possible, learners will need to provide clear examples specific to their workplace.

Learning outcomes 4 and 5

To satisfy the assessment criteria for these learning outcomes, learners demonstrate CAD techniques/drawing displayed on a large monitor with a verbal explanation to colleagues/assessors. Learners will:

1. describe **four** requirements and key features of CAD software in the production of 2D engineering drawings (AC4.1)
2. describe **three** typical features used in the production of 2D drawings, and **three** typical drawing features used in the development of 3D models (AC4.2, 4.3)
3. describe **two** key features of 3D CAD software related to configuration and **two** key features related to display commands (AC4.4)
4. state the meaning of layers and give **three** reasons for using layers in CAD. (AC5.1)
5. describe **six** types of drawing commands typically used to manipulate drawings using CAD (AC5.2)

Where possible, learners will need to provide clear examples specific to their workplace.

Learning outcome 6

To satisfy the assessment criteria for this learning outcome, learners will produce a portfolio of evidence that demonstrates their knowledge of the production of 2D and 3D CAD drawings. Learners will:

1. describe how to produce a 2D CAD assembly drawing consisting of at least **three** component parts (AC6.1)
2. describe how to produce fully dimensioned 2D CAD parts drawings to basic and further CAD commands and BS conventions (AC6.2)
3. describe how to produce a 3D CAD model of the assembly from a 2D CAD assembly drawing that can be rotated and viewed from all sides. (AC6.3)

The portfolio of evidence will include annotated screenshots demonstrating the use of layers, BS8888 standards, drawing templates, finished drawings and models and CAD commands. Additionally, learners will save their work in a recognised electronic format and submit these as part of their portfolio of evidence. Ideally, the drawings will be produced in their learner's workplace.

Unit 9: Electrical and Electronic Principles

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Engineered systems frequently make use of electrical and electronic components, connected together to complete a required function. For example, a microphone collects sound waves of you speaking and converts them into electrical energy in the form of small voltages and currents. The signal from the microphone is then amplified by means of an electronic circuit containing a transistor/integrated circuit, before escaping as your voice from a loudspeaker.

In this unit, you will explore the scientific concepts and principles associated with electrical and electronic systems. You will be introduced to the principles and concepts of electromagnetics and electrostatics. You will discover the difference between alternating current (AC) and direct current (DC) and how these two types of current are used in electrical circuits. Finally, you will gain knowledge of how to calculate the forces on a current-carrying conductor situated in a magnetic field, and the function and use of electromagnetic coils.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the concepts and principles associated with direct current (DC) technologies	1.1	Describe the parameters of direct current electrical circuits
		1.2	Describe total resistance, potential difference and current in series and parallel DC circuits
		1.3	Describe how to determine total resistance, potential difference and current in a DC circuit from data
		1.4	Explain how to compare calculated values with measured readings from pre-constructed circuits
2	Understand the concepts and principles associated with alternating current (AC) technologies	2.1	Describe the parameters of alternating current electricity
		2.2	Describe pure resistance, inductive and capacitive AC circuits
3	Understand the concepts and principles associated with electromagnetic and electrostatic theory	3.1	Describe the principles of electromagnetics and electrostatics
		3.2	Explain how to calculate the force on a current carrying conductor situated within a magnetic field.
		3.3	Describe the force on a current carrying conductor situated in a magnetic field
		3.4	Describe the principal components, operations and uses of an electromagnet

Unit content

What needs to be learned
Learning outcome 1: Understand the concepts and principles associated with direct current (DC) technologies
1A Parameters of direct current • Electrical charge, voltage, electrical current, electromotive force (EMF), electrical resistance, electrical power. **1B Direct current electrical circuits** • Circuit symbols, Ohm's law, potential difference, current, resistance in series and parallel circuit networks, data for calculations.
Learning outcome 2: Understand the concepts and principles associated with alternating current (AC) technologies
2A Parameters of alternating current (AC) • AC waveforms (e.g. frequency, amplitude, period) sinusoidal waveform, AC voltages, AC phase, rectification. **2B Alternating current electrical circuits** • AC resistance and impedance, AC inductance and inductive reactance, AC capacitance and capacitive reactance, series RLC circuit analysis, parallel RLC circuit analysis, phasor diagram.
Learning outcome 3: Understand the concepts and principles associated with electromagnetic and electrostatic theory
3A Parameters of magnetic fields • Magnetic fields, magnetic flux and flux density. • Principles of electromagnetic theory. **3B Magnetic circuits** • Force on a current-carrying conductor. • Components, construction, function and use of electromagnetic coils, e.g. relays, contactors, solenoids, sensors, motors, transformers, data for calculations. **3C Parameters of electrostatics** • Charge, e.g. positive and negative, electrostatic force, Coulomb's law, first and second law of electrostatics. • Principles of electrostatics.

Essential information for tutors and assessors

Essential resources

For this unit, centres need:

- science software packages suitable for Level 2 such as:
  - electrical circuit simulation (DC and AC) software
  - electromagnetism simulation software
- demonstration circuits (hardware)
- multi-meters to demonstrate simple voltage, current measurement on DC circuits
- AC power supplies and oscilloscope to show wave forms
- electromagnets and solenoids.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation that they are familiar with.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a circuit diagram for a DC circuit located in their own organisation or, if they are not in employment, based on an engineering environment with which they are familiar. Learners will:

1. describe the **two** basic ways to connect DC circuits, in series and in parallel. The learner will produce a circuit diagram, which will include at least **three** resistors. Learners will annotate the diagram to describe the parameters of direct current electricity, total resistance, potential difference and the concept of circuits in series and parallel. Learners complete basic calculations for both types of circuit, applying Ohm's law to determine, voltage, current or resistance (AC1.1, 1.2, 1.3, 1.4).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce a phasor diagrams for an AC circuit in their own organisation or, if they are not in employment, based on an engineering workplace with which they are familiar. Learners will:

1. describe, by means of a fully annotated illustration, the parameters of AC electricity, purely resistive AC current, a purely inductive AC circuit and a purely capacitive AC circuit. Learners will annotate the waveforms of the diagram identifying frequency, amplitude and period (AC2.1, 2.2).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a portfolio of calculations and sketches for a simple electromagnetic device in their own organisation or awithin an engineering workplace with which they are familiar. Learners will:

1. describe the parameters for both magnetic fields and electrostatics (AC3.1)
2. explain how to calculate the force on a current-carrying conductor situated within a magnetic field. Learners must then calculate the force on a current carrying conductor using given data (AC3.2)
3. describe the force on a current-carrying conductor situated within a magnetic field with reference to the electro magnetic device (AC3.3)
4. describe the principal components of an electromagnetic coil using a fully annotated sketch. Learners must give examples, with clipped images, of where electromagnetic devices are used (AC3.4).

Unit 10: Fabrication and Welding Principles

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Engineering organisations are commonly required to form or fabricate a part or assembly from metal. A client might require an engineering organisation to form a door panel for a new car or the wing for a plane. Constructing these components requires the use of techniques to permanently join together touching metal surfaces. Typically, this is achieved thermally by welding or by using mechanical pressure.

In this unit, you will gain an understanding of welding and fabrication principles. You will be introduced to common welding and mechanical joining techniques, including the essential tools and equipment. You will discover how these tools and equipment are used and stored safely. You will learn how to read fabrication drawings and patterns for components that require fabrication, gaining knowledge of weld symbols and geometry.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Know the types and application of fabrication hand and machine tools	1.1	Describe the purpose of fabrication hand tools
		1.2	Describe the purpose of fabrication machine tools
		1.3	Explain the safe use and storage of fabrication hand and machine tools
2	Understand fabrication drawings, basic geometry and the application of weld symbols	2.1	Describe the symbols used to represent welds on a fabrication drawing
		2.2	Describe the key parts of a fabrication drawing
		2.3	Describe the basic geometry of welds
3	Understand mechanical joining techniques	3.1	Describe techniques used to mechanically join materials
		3.2	Explain the advantages and disadvantage of mechanical joining techniques
4	Understand thermal joining equipment and techniques	4.1	Describe the features of tools and equipment used to thermally join materials
		4.2	Explain the safe storage of tools and equipment to thermally join materials
		4.3	Describe techniques used to thermally join materials

Unit content

What needs to be learned
Learning outcome 1: Know the types and application of fabrication hand and machine tools
1A Hand tools • Measuring tools: rule, tape rule, protractor, height gauge. • Marking out tools: scriber, centre punch, chalk line, square, trammel, dividers, templates, surface plater, chalk, blueing or paint. • Forming features: datum lines and centre lines, square and rectangular profiles, circles, curved profiles, cutting details, hole centring and circular and linear outlining, punch and dies (e.g. fixed grooved dies, split dies and flat dies). • Cutting tools: tin snips, hacksaw, files, hand power tools (e.g. drill and nibbler). • Forming tools: hammers, mallets, stakes and formers, hand or powered bending. **1B Machine tools** • Cutting: bench shears, guillotine, band saw, pillar drill, punching and cropping machines • Forming: rolling machine, universal press, cylinder press. **1C Safe use and storage** • After use, keep tools clean of dirt, grease and debris by wiping them down with a cloth. • Clean metal surfaces with an approved solution and apply lubricant metal protector spray. • Check tools for damage or defects, and throw away those that cannot be repaired. • Store small hand and power tools on shelving, in a plastic bin or box, long-hand tools can be hung on a wall.

What needs to be learned
Learning outcome 2: Understand fabrication drawings, basic geometry and the application of weld symbols
2A Weld symbols • For example, for seam weld, spot weld, plug weld, filet weld, single-bevel butt weld, single-u butt, weld, butt weld. **2B Key parts of a fabrication drawing** • Drawing style: plan, elevation, details, pattern, orthographic drawing, general arrangement drawings. • Key parts: title block, notes, scale, revision, drawing space. • Line weights: line thickness, centreline, dimension lines. **2C Weld geometry** • Weld geometry, e.g. throat (theoretical, actual), leg, root, toe, face.
Learning outcome 3: Understand mechanical joining techniques
3A Techniques • Clinching, press-joining, bending, hand reaming, riveting, Pittsburgh lock, self-secured joints, riveting (e.g. blind, punch, self-piercing, pop). **3B Advantages and disadvantages** • Advantages: easier disassembly, no change to chemical composition or microstructure of the materials being joined. • Disadvantages: stress is concentrated at the point of attachment, mechanical fastenings are open in nature and moisture, water, air etc. can enter the joint causing corrosion; joints can loosen as a result of vibration or flexing.

What needs to be learned

Learning outcome 4: Understand thermal joining equipment and techniques

4A Tools and equipment

- Tools: safety glasses, auto-darkening welding helmet, chipping hammer, grinder, wire brush, gauntlet cuff gloves (MIG welding), welding jacket, soapstone, pliers, hacksaw, welding tips, air compressor.
- Gas welding equipment: hoses, torches, gas pressure regulators, flow meters; gas supplies; plasma cutters, welder, e.g. TIG, MIG.
- Electric arc equipment: welding cables, electrode holders, welding electrodes, chipping hammer, wire brush, hand screen, PPE, welder, e.g. ARC.

4B Techniques

- Shielded metal arc welding, oxy-acetylene, manual metal arc (MMA), metal inert gas (MIG), metal active gas (MAG), cored wire, Tungsten inert gas (TIG), plasma-arc.
- How welding works: arc, filler metal, flux and shielding, gas, the ground splatter, heat versus thickness, clamps and tacking, bead.
- Type of weld: butt joint, fillet (corner) joint, lap joint, edge joint.

4C Safe storage

- Welding rods stored upright separately in waterproof containers.
- Store hoses in a loose coil, to prevent any folds or creases forming.
- Store welding gas cylinders upright in dry, well-ventilated areas not exposed to heat or the direct rays of the sun.
- Disconnect welder from power supply and store in a secluded area where it will not be bumped or knocked over accidently.

Essential information for tutors and assessors

Essential resources

There are no special resources needed for this unit.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation that they are familiar with.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an annotated tools and equipment list for an ongoing fabrication activity in their own organisation or, if they are not in employment within an engineering organisation with which they are familiar. Learners will:

1. describe the purpose of at least **four** types of fabrication hand tool to be used for the fabrication activity (AC1.1)
2. describe the purpose of at least **four** types of fabrication machine tool to be used for the fabrication activity (AC1.2)
3. explain the safe use and storage of the selected fabrication hand and machine tools. Learners must give details of the actions to take to use and store the tools safely, with valid reasons (AC1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce a simple fabrication drawing for an assembly required for a project in their own organisation or if they are not in employment, based on an engineering workplace with which they are familiar. Learners will:

1. include on their drawing at least **four** types of symbol used to represent welds. For each symbol, learners should include annotation to state the purpose of the symbol (AC2.1)
2. develop at least **three** main parts of an engineering fabrication drawing (for example plan, elevation, detail) to represent the assembly. Learners must annotate the drawing with notes describing the purpose of the key parts (AC2.2)
3. develop a dimension detail for **two** welds, describing **two** types of basic weld geometry. (AC2.3)

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a method statement for an ongoing mechanical joining activity in their own organisation or based on an engineering organisation with which they are familiar. Learners will:

1. describe at least three techniques that might be used to mechanically join materials together. Learners must include details of the actions to take to join materials using these techniques (AC3.1)
2. explain the advantages and disadvantages of using these techniques for the proposed activity or scenario. For each technique, learners must give details of one advantage and one disadvantage (AC3.2).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce a method statement for an ongoing welding activity in their own organisation or, if they are not in employment, based on a work-based scenario. Learners will:

1. outline the features of at least four types of tool and at least four types of equipment used to thermally join materials. Learners must include the purpose of each tool and equipment and how it would be used (AC4.1)
2. explain why it is important to store the tools and equipment used safely when producing fabrications by welding. The four types of equipment and four types of hand tool described above should be used as examples (AC4.2)
3. describe at least three techniques that might be used to thermally join materials together. Learners must include details of the actions they would take to carry out each technique. (AC4)

Unit 11: Manual Welding Techniques

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Welding is a process that joins two metals together by applying heat to melt them, with or without using further molten material. Welding is used extensively in the engineering industry to form joints for metal parts and components. You will find welded joints holding together cars, aircraft, ships, kitchen appliances and a whole range of other equipment. Welding can be achieved through many different techniques, including manual arc, tungsten inert gas, metal active/inert gas and resistance spot welding.

In this unit, you will gain an understanding of how to use these different techniques to produce welded joints. You will learn how to set up different welding equipment and prepare metal workpieces before welding. You will discover how to form and make a weld bead using different techniques, for a range of welded joints, for example fillet, butt, tack or lap. Finally, you will learn about the methods used to identify common welding problems.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Know how to use manual arc welding (MMA) for the production of welded joints	1.1	Describe the set-up of the weld equipment and workpiece for manual arc welding (MMA)
		1.2	Describe the process for making a manual arc welded joint
2	Know how to use Tungsten inert gas (TIG) welding for the production of welded joints	2.1	Describe the set-up of the weld equipment and workpiece for Tungsten inert gas (TIG) welding
		2.2	Describe the process for making a Tungsten inert gas welded joint
3	Know how to use metal active/inert gas (MIG/MAG) welding for the production of welded joints	3.1	Describe the set-up of the weld equipment and workpiece for metal active/inert gas (MIG/MAG) welding
		3.2	Describe the process for making a metal active/inert gas welded joint
4	Know how to use resistance spot welding for the production of welded joints	4.1	Describe the set-up of the weld equipment and workpiece for resistance spot welding
		4.2	Describe the process for making a resistance spot welded joint
5	Know common problems encountered when producing welded joints	5.1	Outline the types of standard welded joints to join together metal workpieces
		5.2	Describe common problems encountered when producing welded joints

Unit content

What needs to be learned
Learning outcome 1: Know how to use manual metal arc welding (MMA) for the production of welded joints
1A Creating a successful MMA weld • Setup equipment, e.g. welding machine, electrodes, clamps and cables, work metal, non-flammable safe work area, personal safety equipment, e.g. welding gloves, helmet, closed toe shoes, welding coat. • Setup workpiece, secure and prepare metal workpiece, metal welding table. • Making the weld, e.g. strike the arc, shape the bead, remove slag/electrode flux.
Learning outcome 2: Know how to use Tungsten inert gas (TIG) welding for the production of welded joints

2A Creating a successful TIG weld
• Set up equipment: Tungsten electrode, TIG welding machine, shielding gas supply, e.g. helium, argon or mixture, filler metal rod, personal safety equipment, e.g. welding gloves, helmet, closed toe shoes, welding coat.
• Setup workpiece, secure and prepare metal workpiece, anti-splatter spray.
• Making the weld:
  ○ select electrode, Tungsten rod point, e.g. ball tip alternating current (AC) power supply or pointed tip direct current (DC) supply)
  ○ power source for type of metal, e.g. alternating current (AC) for aluminium, direct current electrode positive (DCEP) for balling Tungsten tip or stick welding, direct current electrode negative (DCEN) for welding steel
  ○ gas, e.g. pure argon for welding aluminium, or argon/carbon dioxide mixture for welding steel
  ○ form weld bead.

What needs to be learned
Learning outcome 3: Know how to use metal active/inert gas (MIG/MAG) welding for the production of welded joints
3A Creating a successful MIG/MAG weld • Set up equipment: MIG/MAG welding machine, power source, wire feed system (e.g. pinch rolls, push-pull or spool on gun), conduit, gun, shielding gas, personal safety equipment, e.g. welding gloves, helmet, closed-toe shoes, welding coat. • Set up workpiece, secure and prepare metal workpiece, grind a bevel edge on workpiece. • Making the weld: shielding gas, voltage and wire speed setting on the MIG/MAG welding machine, form weld bead.
Learning outcome 4: Know how to use resistance spot welding for the production of welded joints
4A Creating a successful resistance spot weld • Set up equipment: spot welding machine, including the controller, pressure cylinder, water pipes, tool holder, C-type gun, X-type gun and copper alloy electrodes, personal safety equipment, e.g. welding gloves, helmet, closed-toe shoes, welding coat. • Set up workpiece: thin sheet metal, welded wire mesh or wire mesh is held together within the spot welder tool holder. • Making the weld: clamp sheets together between copper alloy electrodes, apply simultaneously pressure and current to a 'spot', the energy locally melts the metal and forms the weld.
Learning outcome 5: Know common problems encountered when producing welded joints
5A Joints • Tack weld, fillet weld, lap weld, butt weld. **5B Common welding problems** • Insufficient shielding gas is surrounding the weld. • The final weld is weak or does not fully join two metal workpieces together. • Weld burns right through the workpiece material. • The weld gun spits and does not maintain a constant weld.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to a workshop with standard welding equipment, including:

- non-flammable, safe working area
- welding equipment for MMA, TIG, MIG/MAG and resistance spot welding
- consumables for welding activities
- work holding devices and equipment
- PPE.

Assessment

This section must be read in conjunction with Section 8 Assessment.

This unit is internally assessed. To pass this unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet for new apprentices on how to produce a standard fillet welded joint for an ongoing fabrication activity within their own organisation or if they are not in employment, for an engineering organisation with which they are familiar. Learners will:

1. describe the set-up of the weld equipment for manual arc welding and the preparation of the metal workpiece to form the fillet joint. Learners must include details of the setup equipment required, including safety equipment, and the setup workpiece. Learners must include details of all stages in the process. (AC1.1)
2. describe the method for forming the weld bead and then making a manual arc welded joint. (AC1.2)

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet on how to produce a standard tack welded joint for an ongoing fabrication activity within their own organisation or if they are not in employment, for an engineering organisation with which they are familiar. Learners will:

1. describe the set-up of the weld equipment for tungsten inert gas welding and the preparation of the metal workpiece to form the tack joint. Learners must include details of the equipment required, including safety equipment, and how to set up the workpiece. (AC2.1)
2. describe the process for forming the weld bead and then making a tungsten inert gas welded joint. Learners must include details of all stages in the process. (AC2.2)

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet on how to produce a standard butt welded joint for an ongoing fabrication activity within their own organisation if they are not in employment, for an engineering organisation with which they are familiar. Learners will:

1. describe the set-up of the weld equipment for metal active/inert gas (MIG/MAG) welding and the preparation of the metal workpiece to form the butt joint. Learners must include details of the equipment required, including safety equipment, and how to set up the workpiece. (AC3.1)
2. describe the process for forming the weld bead and then making a metal active/inert gas welded joint. Learners must include details of all stages in the process. (AC3.2)

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce an information sheet on how to produce a standard spot welded to join two metal sheets together for an ongoing fabrication activity within their own organisation or if they are not in employment, within an engineering organisation with which they are familiar. Learners will:

1. describe the set-up of the weld equipment for resistance spot welding and the preparation of the metal workpiece to form the spot weld. Learners must include details of the equipment required, including safety equipment, and how to set up the workpiece. (AC4.1)
2. describe the method for forming the weld bead and then making a resistance spot welded joint. Learners must include details of all stages of the process. (AC4.2)

Learning outcome 5

To satisfy the assessment criteria for this learning outcome, learners produce a weld report for a completed fabrication activity within their own organisation or alternatively within an educational workshop environment. Learners will:

1. give an overview of the **four** standard welded joints used to join together metal workpieces (AC5.1)
2. give a clear account of at least **three** types of common problem encountered when producing welded joints (AC5.2)

Unit 12: Non-fusion Thermal Joining Methods

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Many modern engineered components and elements found in cars, computers, machinery and plant are required to have complicated and irregular shapes. These components might be formed from a range of different materials, including glass, plastics, composites, polymers, wood, rubber and metal. Accordingly, different methods are required to join components of difficult shapes and distinct materials together.

In this unit, you will gain an understanding of some of these thermal joining methods, exploring the use of soldering, brazing, adhesives and sealants. You will learn about the equipment and workpiece set-up required for brazing and soldering. You will consider how to make a soft soldered or brazed joint. Finally, you will learn about different types of adhesive and sealant, and the advantages and disadvantages of using both to join components.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Know how to join components by soft soldering	1.1	Describe the set-up of the equipment and workpiece component for soft soldering
		1.2	Describe the technique for making a soft soldered joint
		1.3	Explain how to resolve common problems occurring during soft soldering
2	Know how to join components by hard soldering/brazing	2.1	Describe the set-up of the equipment and workpiece component for hard soldering/brazing
		2.2	Describe the technique for making a hard soldered/brazed joint
		2.3	Explain how to resolve common problems occurring during hard soldering/brazing
3	Know how to join components by using adhesives and sealants	3.1	Describe the different types of adhesives and sealants used to join components
		3.2	Describe the different types of materials that can be joined using adhesives and sealants
		3.3	Explain the advantages and disadvantage of using adhesive and sealants to join components together

Unit content

What needs to be learned
Learning outcome 1: Know how to join components by soft soldering
1A Equipment and consumables • Soldering iron, soldering iron stand, prototype board, crocodile clips, rosin core solder, steel wool, solder braid. **1B Technique** • Heat soldering iron, clean tip on sponge, complete tinning of soldering iron tip, clean workpiece components with steel wool, heat connection, apply solder. **1C Common problems** • Solder will not flow, connection grainy/crystalline, tip is oxidised, too much/too little solder.
Learning outcome 2: Know how to join components by hard soldering/brazing
2A Equipment and consumables • Brazing torch, striker, glasses, respirator, clamps, brazing alloy rods, acetylene gas, propane, natural gas, steel wool, flux. **2B Technique** • Clean workpiece components with steel wool, clamp workpieces, heat joint, apply blazing rod, remove oxidation/residue from complete joint. **2C Common problems** • Improper fluxing, braze joint is too thin, uneven solder, wrong brazing temperature, gas entrapment, cold anvil.

What needs to be learned

Learning outcome 3: Know how to join components by using adhesives and sealants

3A Types of adhesive and sealant

- Adhesives: wood glues (types I to III), cyanoacrylate adhesive (superglue), hot glue, pressure sensitive adhesives, spray adhesives, epoxy resin, polyurethane glue.
- Sealants: butyl rubber, epoxy, foam, latex, plastic, polysulphide, silicone.

3B Types of material to bonded

- Metal, polymer glass, rubber, ceramic, composite, polymers, wood.

3C Advantages and disadvantages of using adhesive and sealant bonds

- Advantages: distribute stress load evenly over a broad area, can be invisible, resist flex and vibration, protect joint against corrosion, join irregular shapes, negligibly increase the weight of assembly, assembly can be automated.
- Disadvantages: amount of time to fix and develop full strength, surface preparation requirements, joint disassembly is difficult.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to a workshop with standard soft soldering and brazing/hard soldering equipment.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners prepare a guidance sheet on how a soft soldered joint can be used to join material for a component used in their own organisation or, if they are not in employment, within an engineering organisation with which they are familiar. Learners will:

1. give a clear account of the setup of the equipment and workpiece, including at least **six** items of equipment or consumables (AC1.1)
2. outline the technique deployed for forming a soft soldered joint, including the main stages of the technique (AC1.2)
3. give details of at least **three** common problems encountered when completing soft soldering, with examples for each on how to resolve them (AC1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners add to their guidance sheet to describe how a hard soldered/brazed joint can be used to join material for a component in their own organisation or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. give a clear account of the setup of the equipment and workpiece, which will include **six** items of equipment or consumables (AC2.1)
2. outline the technique deployed for forming a hard soldered/brazed joint, including the main stages of the technique (AC2.2)
3. give details of **three** common problems encountered when completing hard soldering/brazing, with examples for each on how to resolve them (AC2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners add guidance for the use of adhesive and sealants used in their own organisation or, if they are not in employment, an organisation with which they are familiar. Learners **will**:

1. outline **three** types of sealant and **three** types of adhesive, setting out the main characteristics of each (AC3.1)
2. give a clear account of the types of materials that can joined by each type of selected sealant or adhesive to form a component (AC3.2)
3. explain **one** advantage and **one** disadvantage of using each type of adhesive or sealant to join the parts of a component produced in a given material, with valid reasons for each (AC3.3).

Unit 13: Engineering Maintenance Safety Practices

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Planned maintenance is a scheduled activity carried out by a competent engineer to ensure that an item of plant, machinery or equipment is operating correctly and that it is in a fully serviceable condition. Planned maintenance is completed to maintain operability and therefore avoid any unscheduled breakdown or downtime. Maintenance activities are also completed to find and fix faults affecting the operation of plant, machinery or equipment. Maintenance practices must be planned and undertaken safely, considering appropriate legislation and the impact on the environment.

In this unit, you will gain an understanding of your own and others' responsibilities for safety when planning a maintenance activity. You will learn how to identify typical hazards and risks associated with maintenance and discover how to set up a safe working area with appropriate provision for emergencies. You will explore typical maintenance activities, gaining an appreciation of how to handle materials and equipment safely during maintenance operations. Finally, you will consider the environmental legislation that has an impact on engineering maintenance, and you will understand how to mitigate potential environmental issues during operational engineering maintenance.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the safety requirements of maintenance operations	1.1	Describe the safe handling of materials and equipment during maintenance operations
		1.2	Describe the selection and use of personal protective equipment (PPE) during maintenance operations
2	Know how to plan a maintenance job in a workplace	2.1	State typical risks and hazards associated with undertaking a maintenance job in the workplace
		2.2	Describe the emergency procedures to be followed in response to an incident in an engineering workplace
		2.3	Describe how to provide a safe work area in an engineering workplace
3	Know how to prepare for maintenance operations	3.1	Describe the typical activities undertaken as part of maintenance operations
		3.2	Describe how to prepare for engineering maintenance activities
4	Understand environmental considerations when undertaking maintenance operations	4.1	Describe environmental legislation and policy governing engineering maintenance operations
		4.2	Describe mitigation methods to control typical environmental issues during engineering operations

Unit content

What needs to be learned
Learning outcome 1: Understand the safety requirements of maintenance operations

1A Material and equipment handling
• Own and others' roles and responsibilities, e.g. under:
  ○ Health and Safety at Work etc. Act 1974
  ○ Management of Health and Safety at Work Regulations
  ○ Workplace Health and Safety and Welfare Regulations
  ○ Personal and Protective Equipment at Work Regulations
  ○ Manual Handling Operation Regulations
  ○ other current and relevant legislation applicable to the working environment.
• Identification of warning signs for the seven main groups of hazardous substances (explosive, flammable, oxidising, corrosive, acute toxicity, hazardous to the environment, health hazard), e.g. as defined by the Classification, Labelling and Packaging of Chemicals Regulations (CLP); sources of information and guidance in an organisation.
• Using equipment safely, e.g. mechanical, electrical, fluid power equipment; lifting and carrying techniques; housekeeping, e.g. tidy workspace, protecting others from harm.
1B Personal protective equipment (PPE)
• Appropriate to task undertaken, e.g. overalls, protective footwear, eye protection, mask/respirators.

What needs to be learned

Learning outcome 2: Know how to plan a maintenance job in a workplace

2A Hazards and risks

- Hazards: working environment, e.g. working at height, electricity, confined spaces, hot working; tools and equipment; materials and substances; dangers of not working to laid down procedures.
- Risks: chance or probability that someone will be harmed or experience adverse health effects if exposed to a hazard.

2B Emergency procedures

- Engineering workshop incidents (accidents/injury, work hazards, fire); identification of appropriate qualified person, e.g. first aider, fire warden; actions in the event of an accident or emergency, e.g. use of fire extinguisher (types and application), types of and sounding/initiating emergency alarm, evacuation procedure and escape routes; reporting routines, e.g. at assembly point, hazards and malfunctions; injury, near miss occurrence.

2C Providing a safe working area

- Authorised personnel undertake maintenance; prevent unauthorised access to working area, e.g. barriers, signs, safe routes; isolation of machines from energy sources, lock-off; permit to work.

Learning outcome 3: Know how to prepare for maintenance operations

3A Engineering work activity

- Types of activity, e.g. commissioning/installing equipment or systems, machining/manufacturing a product or component, servicing/maintenance of plant or equipment, construction/testing of circuits.
- Prepare work environment, e.g. area free from hazards, safety procedures implemented, PPE and tools obtained and checked (safe and usable condition).
- Prepare for activity, e.g. all necessary drawings, specifications, job instructions, materials/components obtained, storage arrangements for work, authorisation to carry out work.
- Complete work activity, e.g. all tasks and documentation, return drawings/ work instructions and tools, dispose of unusable tools, equipment, components and waste materials (oil, soiled rags, swarf/off cut).

What needs to be learned
Learning outcome 4: Understand environmental considerations when undertaking maintenance operations
4A Environmental considerations • Legal obligations, current codes of practice, environmental organisations and consultee policy documentation, environmental impact statement, environmental issues and effects, e.g. maintaining sustainable resources, air quality, water quality, waste volumes; mitigation measures, e.g. use of renewable materials, appropriate waste disposal, spill control, safe chemical storage, safe oil storage.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to a workshop with standard welding equipment.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a method statement for an ongoing maintenance operation in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe the safe handling of materials and equipment during the maintenance operation. Learners must include details of the type of method and/or equipment to use, and actions to take (AC1.1)
2. describe the selection and use of at least two items of PPE required during the maintenance operation. Learners must include the reasons for selecting the PPE and how to use it (AC1.2).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners undertake an observed tool-box talk for an ongoing maintenance activity in their own organisation or, if they are not in employment, an engineering organisation with which they are familiar. Learners will:

1. describe at least **five** hazards associated with undertaking the maintenance job in the engineering environment. Learners must provide details of the risks the hazards could lead to if not minimised (AC2.1)
2. describe the emergency procedure to be followed in response to an incident, for example fire or injury to a member of staff, during the maintenance activity. Learners must include the actions to take in the correct sequence (AC2.2)
3. describe how to provide a safe work area in the workplace where the maintenance activity is to be undertaken. Learners must provide details of actions to take and the roles of authorised personnel (AC2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a maintenance report for an ongoing application in their own organisation or, if they are not in employment, in an engineering environment with which they are familiar. Learners will:

1. describe at least **four** planned and **four** unplanned types of maintenance activity undertaken in their industry sector. Learners must provide details of actions to take to carry out each activity (AC3.1)
2. describe how to prepare for the identified planned and unplanned maintenance activities. Learners must include actions to take to prepare for each activity (AC3.2).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce an environmental statement for an ongoing maintenance activity in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe at least **two** pieces of environmental legislation and **two** policies governing the engineering maintenance operation. Learners must include the main requirements of each in relation to the ongoing maintenance activity (AC4.1)
2. describe at least **two** mitigation methods used to control environmental issues during the ongoing maintenance activity. Learners must identify the method and give details of the purpose of the method, and actions to take to carry out the method (AC4.2).

Unit 14: Engineering Maintenance Planning

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Planned maintenance is a scheduled activity carried out by a competent engineer to ensure that an item of plant equipment and systems is operating correctly and that it is in a fully serviceable condition. Planned maintenance is completed to maintain operability and therefore avoid any unscheduled breakdown or downtime. Unplanned maintenance activities are completed to find and fix faults affecting the operation of plant, machinery or equipment. Maintenance activities are critical to the successful continued operation of, for example, trains, aircraft, ships, and the plant, machinery and equipment used in their manufacture.

In this unit, you will gain an understanding of why maintenance activities and condition monitoring are undertaken for engineering plant, equipment and systems. You will explore different types of maintenance activity and gain an appreciation of the resources and documentation required to undertake maintenance tasks successfully. You will consider the frequency of planned maintenance activities and the techniques used for the condition monitoring of engineering plant, equipment and systems.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Know how to determine engineering maintenance requirements for plant equipment and systems	1.1	Describe the reasons for maintaining engineering plant, equipment and systems
		1.2	Describe typical parts of engineering plant, equipment and systems requiring maintenance
		1.3	Describe typical causes of equipment failure
		1.4	Explain how to ascertain maintenance requirements for plant, equipment and systems
2	Know how to plan for essential engineering maintenance	2.1	Describe the resources needed to carry out an engineering maintenance activity
		2.2	Describe the frequency of planned engineering maintenance activity
3	Understand methods for completing engineering maintenance of plant, equipment and systems	3.1	Describe the documentation required to complete an engineering maintenance activity
		3.2	Describe types of maintenance activity
4	Understand how to complete engineering condition monitoring of plant, equipment and systems	4.1	Describe techniques used for the condition monitoring of engineering plant, equipment and systems
		4.2	Explain the need to monitor the condition of engineering plant, equipment and systems

Unit content

What needs to be learned
Learning outcome 1: Know how to determine engineering maintenance requirements for plant, equipment and systems
1A Cause and effects • Causes of equipment failure, e.g. age, wear, vibration, corrosion, fouling, environment, lack of maintenance. • Effects, e.g. importance of downtime, increased cost, equipment/component life. **1B Maintenance activity** • Maintenance undertaken for specific part of an engineering system, e.g. pump, valve, compressor, heating, lighting, fluid power, manufacturing or test equipment. **1C Reasons for maintenance** • Ensure plant, equipment and systems run smoothly and reliably, prevent breakdowns, repair faults, comply with health and safety legislation. **1D Determining maintenance requirements** • Maintenance plan, fault identification and reporting, when to refer faults and to whom (competent/qualified person), health and safety legislation requirements.
Learning outcome 2: Know how to plan for essential engineering maintenance
2A Identification of resources • Availability of maintenance and production staff; appropriate documentation, e.g. permit-to-work, maintenance checklists, production schedules, machine/process records, handover documents, equipment manuals; fault-finding aids; appropriate spares/materials/consumables; appropriate test equipment and tools. **2B Maintenance planning** • Frequency of maintenance; reasons for selecting different frequency rates for specific maintenance, e.g. on shift/daily/weekly/monthly/yearly routines; identification of planned repairs/replacement; health and safety issues; environmental issues; estimation of cost.

What needs to be learned

Learning outcome 3: Understand methods for completing engineering maintenance of plant, equipment and systems

3A Maintenance documentation

- Information, e.g. manufacturers' manuals, drawing charts and diagrams, planning sheets, instructions, schedules; recording, e.g. maintenance logs, other records; handover documents; fault-finding aids.

3B Type of maintenance procedures

- Planned maintenance, e.g. routine maintenance, preventative maintenance, conditioning monitoring, front-line maintenance and when/where they are used, servicing.
- Unplanned maintenance, e.g. breakdown, repair, equipment failure, run to failure.

Learning outcome 4: Understand how to complete engineering condition monitoring of plant, equipment and systems

4A Monitoring techniques

- Techniques, e.g. failure mode and effective analysis (FMEA), vibration analysis, lubricant analysis, acoustic emissions, infrared thermography, ultrasound testing, self-diagnostic and computerised systems.

4B Need for monitoring

- Physical aspects, e.g. improve safety, reduced environmental hazards, extend the equipment's life, ensure accurate equipment performance.
- Cost-related aspects, e.g. improve product quality, reduce downtime, reduce cost.
- Other aspects, e.g. produce comprehensive computer database, better communications.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to a maintenance workshop with standard equipment, including:

- accelerometer
- compound gauge
- pressure gauge
- thermal camera
- acoustic emissions sensor.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a guidance sheet for a maintenance activity in their own organisation or, if they are not in employment, in an engineering workplace with which they are familiar. Learners will:

1. give at least **four** reasons why it is necessary to undertake maintenance activities for engineering plant, equipment and systems. Learners must include details of the consequences if the plant, equipment and systems are not maintained (AC1.1)
2. describe at least **four** typical parts of engineering plant, equipment or systems requiring maintenance. Learners must include details of the purpose of each part and actions to take to ascertain the maintenance requirements of each part (AC1.2)
3. give **three** reasons why plant, equipment or systems can fail (AC1.3)
4. explain how to ascertain maintenance requirements for plant, equipment and systems with clear examples for each (AC1.4)

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners fill in a planned maintenance log for an item of plant or equipment, or for a system in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners **will**:

1. describe at least **four** resources needed to carry out the maintenance of the item of plant, equipment or system. Learners must include details of the purpose of each resource (AC2.1)
2. describe the frequency of the maintenance activity necessary to keep the item of plant, equipment or system in serviceable condition. (AC2.2)

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a summary or introductory page for a maintenance logbook for an item of plant or equipment or for a system in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe at least **five** documents required to complete the maintenance activities discussed as being necessary to maintain the identified item of plant or equipment, or system. Learners must include details of the content of each and their role in engineering maintenance (AC3.1)
2. describe at least **two** types of planned and **two** types of unplanned engineering maintenance activity necessary to maintain an identified element of plant, equipment or system. Learners must include details of actions to take to complete the maintenance activity (AC3.2).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce instructions for a technique adopted to complete condition monitoring for an item of plant, equipment or system in their own organisation or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. describe the key procedural steps of the techniques used for the condition monitoring of the selected item of engineering plant, equipment and system. Learners must select the correct technique for the selected item of engineering plant, equipment and system and the details of each step in order (AC4.1)
2. give at least **three** reasons why it is necessary to complete condition monitoring of the identified item of plant, equipment or system. (AC4.2)

Unit 15: Engineering Materials Processes

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

In today's modern world, we rely on many engineered items to complete our daily activities, from motor vehicles, to washing machines, computers and games consoles. In order to manufacture these items, engineers will make decisions about the appropriate materials to be used in their assembly. It is vital, therefore, that engineers are aware of the properties, composition and uses of engineering materials.

In this unit, you will gain an understanding of the physical and mechanical properties of engineering materials, the effect of working and heat treatment on engineering material properties and how these materials corrode when subject to environmental effects. You will consider the composition of metal, polymer and composite engineering materials and how they materials are used to produce engineering products. You will explore the manufacturing process for materials, gaining an appreciation of how materials are extracted, supplied, processed and recycled.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the physical and mechanical properties of engineering materials and the principles of corrosion	1.1	Describe the physical properties of common engineering materials
		1.2	Describe the mechanical properties of common engineering materials
		1.3	Describe the principles governing the electrochemical process of corrosion
2	Understand the effect of working and heat treatment on engineering material properties	2.1	Describe the effect of working on common engineering materials
		2.2	Describe the effect of applying heat treatments to common engineering materials
		2.3	Describe the effect of applying surface treatments to common engineering materials
3	Understand the composition of materials and material uses	3.1	Describe the composition of metal, polymer and composite engineering materials
		3.2	Describe typical engineering uses for common engineering materials
4	Understand primary and secondary forming processes used to produce engineering materials	4.1	Describe the production life cycle for common engineering materials
		4.2	Describe primary processing techniques applied to common engineering materials
		4.3	Describe the secondary processing techniques applied to common engineering materials

Unit content

What needs to be learned
Learning outcome 1: Understand the physical and mechanical properties of engineering materials and the principles of corrosion
1A Physical and mechanical properties of materials • Physical – mass, density, melting point, thermal conductivity, electrical conductivity, magnetic, opacity, translucence, transparency. • Mechanical – tensile strength, compressive strength, hardness, toughness, brittleness, malleability, ductility, Young's modulus, stiffness. **1B Principles of corrosion** • Oxidation, reduction, electrochemical reaction, corrosion resistance, electromotive force series, anode, cathode, electrolyte and oxidising species. **1C Common engineering materials** • Ferrous materials, e.g. cast iron, low and high carbon steel, stainless steel. • Non-ferrous materials, e.g. aluminium, brass, bronze, copper, lead. • Organic materials, e.g. hard and soft woods. • Thermoplastics, e.g. PVC, nylon, PTFE, polythene, Perspex®. • Thermosetting polymer, e.g. Bakelite, Formica®, melamine, Kevlar™ epoxy resin, polyester resin. • Smart materials, e.g. piezoelectric materials, shape memory alloys, magneto-rheostatic fluids, electro-rheostatic fluid. • Composites, including wood composites, e.g. plywood, reinforcing material (glass fibres, carbon fibres, wood flour).

What needs to be learned
Learning outcome 2: Understand the effect of working and heat treatment on engineering material properties
2A Treatments • Surface treatments – electro-plating, painting, plastic coating, anodising, galvanising. • Heat treatments – annealing, hardening, tempering. **2B Working** • Cold working or cold forming, e.g. rolling, squeezing, bending, shearing and drawing. **2C Effects** • Prevents rusting and deterioration, improves strength, alters physical and chemical properties, increases or reduces hardness or ductility.
Learning outcome 3: Understand the composition of materials and material uses
3A Composition of materials • Metals – crystal lattice structure, grain structure, crystal growth. • Polymer material – monomer, polymer, polymer chains. • Composite material – particulate, laminar, fibre reinforcement, fibre alignment. **3B Material uses** • Aerospace, e.g. engines, wings, rotor blades, landing gear. • Automotive, e.g. engines, body panels, wheels, suspension parts, braking systems. • Marine, e.g. engines, sonar masts, propellers, chains/anchors. • Communications, e.g. satellite dish, smartphone, wireless router, transmission mast. • Electrical/electronic, e.g. washing machine, television, games consoles, sensors.

What needs to be learned

Learning outcome 4: Understand the primary and secondary forming processes used to produce engineering materials

4A Life cycle of engineering materials.

- Extraction – mining, mineral ore, crude oil.
- Processing of raw materials and products – energy uses and waste during processing, transportation, oil by-products.
- Use: recycling and disposal – reusing materials and products, recycling material, disposal of material (hazardous and non-hazardous), biodegradation.

4B Forms of material supply

- Metal form types – bar stock, sheet materials, pipe/tube, plate, casting, forgings, extrusions, wire, powder.
- Polymer/composite form types – bar stock, sheet, pipe/tube, mouldings, powders, granules, resins, film.

4C Primary forming processes

- Forging, extrusion, rolling, sheet metal working, rotary swaging, thread rolling, explosive forming, electromagnetic forming.

4D Secondary forming processes

- Machining, heat treatments, coatings.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to an engineering workshop.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners complete a material production template sheet for an engineering component used in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe at least **two** physical properties and **two** mechanical properties of the materials used in the production of the identified engineering component (AC1.1, 1.2)
2. outline the principles of the electrochemical process of corrosion that will affect the materials used in the production of the identified engineering component (AC1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners recommend a performance improvement for a material forming part of an engineering component used in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe the effect of applying at least **one** material working technique to a material forming part of the engineering component (AC2.1)
2. describe the effect of applying at least **one** heat treatment to a material forming part of the engineering component (AC2.1)
3. describe the effect of applying at least **one** surface treatment to a material forming part of the engineering component (AC2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a summary or introductory page for a materials handbook for use in their own organisation or, if they are not in employment, in an engineering environment with which they are familiar. Learners will:

1. describe the composition of metal, polymer and composite engineering materials. Learner descriptions could be in the form of annotated diagrams provided by the tutor (AC3.1)
2. outline at least **five** typical engineering uses for common engineering materials. Learners must include at least **one** use for metal, **one** use for polymer and **one** use for composite material, using examples from their own engineering environment where appropriate (AC3.2).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce a manufacturing process plan for a material used with an engineering component in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe the production life cycle for the identified engineering material. Learners must include details of the extraction, processing, use, recycling and disposal stages (AC4.1)
2. describe at least **two** primary processing techniques that are applied to the identified engineering material. Learners must include details of the purpose of the techniques and how to carry them out (AC4.2)
3. describe at least **one** secondary processing technique that is applied to the identified engineering material. Learners must include details of the purpose of the technique and how to carry it out (AC4.3).

Unit 16: Plan and Carry out a Project in Engineering

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Engineering organisations frequently undertake projects that vary in terms of extent and purpose. An engineering project might encompass the milling of a new part for a plane or the retrofitting of a bearing for a train. However, all projects must be planned through a series of key stages if a successful project outcome is to be achieved. Most projects typically start with the definition of a need, which is often expressed as a goal. Engineers will then work to establish the engineering criteria and constraints governing the achievement of that goal, before presenting design solutions. The chosen solution might then be built as a prototype, tested or evaluated before being fully commissioned.

In this unit, you will gain an understanding of the importance of planning an engineering project. You will be introduced to the typical management stages of a project and gain an appreciation of how stakeholders influence a project's goals. You will learn how the management of a project is primarily concerned with preventing, or, where this is not possible, reducing the different project risks that can have an impact on success. You will discover how to plan a project and to monitor ongoing project progress. Finally, you will learn how to review projects in order to take forward key lessons.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the importance of planning an engineering project	1.1	Describe the different types of stakeholder who influence engineering projects
		1.2	Describe the key management stages of an engineering project
		1.3	Describe the risks that must be managed in engineering projects
		1.4	Explain the consequences of risks not being successfully managed
2	Know how to create a project plan	2.1	Describe the key features of a project plan
		2.2	Describe the purpose of the key features of a project plan
		2.3	Describe methods used to prepare a project budget
3	Know how to monitor the progress of a project against a project plan	3.1	Describe tools used to manage the progress of a project
		3.2	Describe the main features of a Gantt chart
4	Understand how to review the success of a project	4.1	Describe methods used to gather feedback on an engineering project
		4.2	Describe how feedback on an engineering project is shared and used

Unit content

What needs to be learned
Learning outcome 1: Understand the importance of planning an engineering project
1A Project stakeholders • Client, internal customers, external customers, regulatory authorities, government agencies, suppliers, contractors and subcontractors. • Stakeholder analysis – power versus interest and stakeholder management. **1B Management stages of an engineering project** • Project initiation, including project proposal, feasibility study, project controls and communication strategy, project planning, project implementation and closure. **1C Project risks** • Types: health, safety and welfare, workforce experience, complexity and core technical considerations, availability of resources, poor quality; information management and project stage decision making. • Risk management plan, including risk identification (risk registers), risk assessment; prevention, reduction and protection; impact on business.
Learning outcome 2: Know how to create a project plan
2A Features of a project plan • Outline plan, including purpose, aims, objectives, scope, constraints, deliverables, targets communications and controls. • Resource plan, including physical, technological and human resources. • Financial plan, including budget spend, costing, pricing and sources of finance. • Quality plan, including quality targets and quality control methods. • Contingency plan, including allowing time and budget for risks related to physical, technological and human resources issues. • Project schedule, including activities involved, order of completion and timings. **2B Methods used to prepare a project budget** • Methods, e.g. forecasts, budgets, cash flow, contingencies, delays, costing risk, measurement. • Budget headings, e.g. labour, material, travel, administrative, equipment, plant, liabilities, consumables, subcontractor.

What needs to be learned
Learning outcome 3: Know how to monitor the progress of a project against a project plan
3A Tools to manage project progress • Digital timeline model, bar charts, flow charts, network analysis, critical path analysis, line of balance, time chainage, actions lists, method statements. **3B Features of Gantt charts** • Sequence of activities, duration of activities, concurrent activities, dependent activities, minimum completion time, slack time (float), critical activities, delays and adjustments.
Learning outcome 4: Understand how to review the success of a project
4A Methods used to gather feedback • Completion figures, e.g. deliverables, scope, time, cost; issues logs, complaints analysis, completion questionnaires. **4B Uses of feedback at the end of an engineering project** • Measuring stakeholder satisfaction, identifying lessons learned, driving business improvements, including training, expertise, documentation and procedures; informing future projects, recognising project successes and failures.

Essential information for tutors and assessors

Essential resources

There are no special resources needed for this unit.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the assessment criteria and achieve the learning outcomes to the same standards as demonstrated in the recommended assessments below.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a project information leaflet for a new apprentice in their project team, for an ongoing project in their own organisation, or, if they are not in employment, in an organisation with which they are familiar. Learners **will**:

1. outline at least **four** types of project stakeholder. For each stakeholder, learners must give **one** detailed example of their influence on the formation of an engineering project (AC1.1)
2. outline at least **four** key management stages of an engineering project. Learners must include the purpose of and the main actions involved in each stage (AC1.2)
3. describe at least **five** risks that must be managed throughout the engineering project (AC1.3)
4. explain the consequences of not managing these risks with one example for each risk (AC1.4).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners could produce a simple plan for an ongoing project in their own organisation, or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. develop a flow chart outlining at least **four** key features of a typical detailed engineering project plan, including a description of their purpose (AC2.1, 2.2)
2. describe at least **two** ways in which budgets are prepared and why budget headings are important (AC2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a Gantt chart for an ongoing project in their own organisation, or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. describe at least **three** tools that could be used to manage the progress of the project (AC3.1)
2. develop a Gantt chart to illustrate the sequence and duration of activities for the project and describe at least **four** key features of the chart such as critical activities and any slack time embedded to account for delays and or contingency for risks (AC3.2).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners prepare a project review form to use on the completion of a project in their own organisation, or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. describe at least **two** key methods that can be used to gather feedback on the completion of a project. Learners must include details of the type of feedback and how it is gathered (AC4.1)
2. explain how the feedback could be used by the project team at the end of the project. Learners must explain at least **two** uses of the feedback, with at least **one** valid reason for each use (AC4.2).

Unit 17: Engineering Manufacturing Techniques

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

In today's modern world, we rely on many engineered products to complete our daily activities, from motor vehicles, to washing machines, computers and games consoles. In order to produce these items, engineers will plan, monitor and control every step of the manufacturing process. They will define and introduce quality control systems to ensure that a manufactured engineering product or component fully conforms to the original designer's specification. Engineers will check and inspect the dimensional and geometrical accuracy of key attributes of the engineered product or component at key stages of manufacture.

In this unit, you will gain an understanding of the different scales and key stages of the manufacture of an engineering product or component. You will learn about the different types of equipment used in this manufacture and consider how product quality is monitored and controlled. You will explore the content of a production plan and specification, and determine the time, labour and material costs of manufacture. Finally, you will learn about key completion activities following manufacture.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Know how to prepare for the manufacture of an engineering product	1.1	Describe the content of a production plan used to prepare for the manufacture of an engineering product
		1.2	Describe the content of a product specification used to prepare for the manufacture of an engineering product
		1.3	Explain how to determine the time, labour and material costs for the manufacture of an engineering product
2	Know how to manufacture an engineering product	2.1	Describe the different scales of manufacture that can be used to create an engineering product
		2.2	Describe, using a block diagram, the key stages of manufacture of an engineering product
		2.3	Describe the different types of equipment used to manufacture an engineering product
3	Know how to monitor and control the manufacture of an engineering product	3.1	Describe equipment used to monitor and control the manufacture of an engineering product
		3.2	Describe dimensional and geometric attributes that need to be monitored and controlled during the manufacture of an engineering product
		3.3	Describe a quality control system used to monitor and control the manufacture of an engineering product

Learning outcomes		Assessment criteria	
4	Know how to complete the manufacture of an engineering product	4.1	Describe the key completion activities for the manufacture of an engineering product
		4.2	Describe typical tolerance limits used to inspect completed engineering products

Unit content

What needs to be learned
Learning outcome 1: Know how to prepare for the manufacture of an engineering product
1A Production plan • Sequence of processes for an engineering activity. • Tools and equipment required. • Speed and feed. • Quality and inspection requirements. • Health and safety precautions, environmental or legislative requirements. **1B Product specification** • Information required for product manufacture, e.g. production drawings, production quantities and delivery rates, quality specifications, parts and materials to be used, processing methods specified in the design. **1C Related data and information** • Calculation of processing time, e.g. set-up time, first off proving, batch/quantity manufacture, inspection, sign off. • Cost of plant, tooling, jigs, fixtures cost of materials and components, cost of labour.
Learning outcome 2: Know how to manufacture an engineering product
2A Scales of production • Jobbing; small batch; repeated batch; continuous production. **2B Manufacturing process** • Representation by block diagram; key stages of production to include material and component preparation, material processing, product assembly and finishing, packaging and dispatch. **2C Types of equipment** • Special dedicated, general purpose, computerised, automated. • Boring machines, milling machines, grinders, drills, shaping machines, hydraulic machines, lathes, mechanical presses.

What needs to be learned
Learning outcome 3: Know how to monitor and control the manufacture of an engineering product
3A Monitoring equipment • Dimensional equipment: micrometres, e.g. external, internal, depth, steel rules, vernier calipers, straight edge, engineer's try-square, bevel protractors, combination sets, toughness comparison specimens, gauges, e.g. slip, radius, plug, gap, taper, ring. • Comparators: dial test indicators, e.g. plunger types, level types; simple mechanical comparator, e.g. Sigma comparator, inside caliper, outside caliper. **3B Attributes to be controlled** • Dimensional, e.g. length, diameter, depth, flatness, parallelism, angle. • Geometric, e.g. profiles, roundness, concentricity, accuracy of form, surface texture, roughness. **3C Quality control** • Definition of quality, e.g. fitness for purpose, safe to use, meeting the customer's requirements, meeting quality standards ISO9001. • System: quality control department, documents used, role of inspection, frequency of inspection, provision for traceability, calibration.
Learning outcome 4: Know how to complete the manufacture of an engineering product
4A Completion • Post-production, product durability, shipping, golden sample, production review. **4B Tolerances** • Concept of tolerances, ISO system of limits and fits, hole basis system, use of British Standards, e.g. BS4500, types of fit, clearance, transition, interference.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to a workshop with:

- standard welding equipment
- hand tools
- machine tools.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce an information chart reviewing the content of both a production plan and specification used in their own organisation or, if they are not in employment, an organisation with which they are familiar. Learners will:

1. describe the basic content of both a production plan and specification on an information chart, including at least **four** components of each document (AC1.1, AC1.2).
2. explain how to complete basic calculations to quantify the cost of time, labour and materials to manufacture a simple engineering product, with examples of each calculation (AC1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce a portfolio describing the manufacture of an engineering product in their in their own organisation or, if they are not in employment, an organisation with which they are familiar. Learners will:

1. give a clear account of the scales of manufacture that can be undertaken in industry, describing at least **four** different scales, before recommending a scale of manufacture for the engineering product to be produced (AC2.1)
2. use a block diagram to describe the key stages of manufacture of an engineering product including all stages listed in the content (AC2.2)
3. give a clear account of at least **five** types of equipment that can be used in the manufacturing process of an engineering product, including details of their use and purpose (AC2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a guidance document covering the monitoring and control of the manufacture of an engineering product in their own organisation or, if they are not in employment, an organisation with which they are familiar. Learners will:

1. outline the use of at least **10** items of equipment used to monitor and control the manufacture of an engineering product (AC3.1)
2. clearly describe the dimensional or geometrical attributes each item of equipment is designed to check (AC3.2)
3. define quality and describe at least **four** systems that can be introduced in an engineering manufacturing organisation to maintain quality (AC3.3).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce a flow chart illustrating completion activities for an engineering product manufacture in their own organisation or, if they are not in employment, an organisation with which they are familiar. Learners will:

1. produce an annotated flow chart that includes details of at least **four** activities to be carried out following completion of the production of an engineering product (AC4.1)
2. review an inspection sheet and describe at least **three** types of tolerance, checked following completion of a product (AC4.2) .

Unit 18: Engineering Design Techniques

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Engineering organisations have large teams of skilled engineers who work collectively to produce a product or assembly. An important part of the development of a product or assembly is the planning stage. Engineers must capture and express the exact requirements of their customer or client in a product design proposal. Once these requirements are fully documented, engineering teams focus on the achievement of the requirements by determining the components, subsystems and technical characteristics of the product solution and recording them in the product design specification.

In this unit, you will gain an understanding of engineering design techniques. You will learn how to develop a product design specification and product design proposal. You will discover the criteria and constraints that influence a product design solution and how to select a final product solution. Finally, you will learn about the methods used to evaluate the product solution.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Know how to develop a product design specification	1.1	Describe the content of a product design specification
		1.2	Describe the key stages involved in preparing a product design specification
2	Understand how to prepare a product design proposal	2.1	Describe the content of a product design proposal
		2.2	Describe the key stages involved in preparing a product design proposal
		2.3	Explain the purpose of the key stages of the product design proposal
3	Understand how to prepare a final product design solution	3.1	Describe the design criteria and constraints that can influence the design of a product solution
		3.2	Explain the criteria influencing the choice of the selected product solution
4	Understand how to evaluate a final product design solution	4.1	Describe the methods used to evaluate a final product design solution
		4.2	Describe the type of test data used during the evaluation of a final product design solution
		4.3	Evaluate the final product design solution

Unit content

What needs to be learned
Learning outcome 1: Understand how to develop a product design specification
1A Product design specification • Information required for manufacture of a product or assembly, e.g. production drawings, production quantities and delivery rates, subsystem blueprints, software requirements, maintenance requirements, finishes, material choices, sustainability, safety requirements, manufacturing methods. **1B Process of preparing a product design specification** • Define performance and technical characteristics; prepare quality specifications. • Component requirements and connectivity, determine parts and materials to be used. • Processing methods specified in the design.
Learning outcome 2: Understand how to prepare a product design proposal
2A Product design proposal • Information identifying product needs and requirements, e.g. functional requirements, benefits of the product to the end customer, objectives of the product, strategy and plan of action for achieving the product objectives. **2B Process of preparing a product design proposal** • Key stages (set and prioritise goals with stakeholders and customers, define deliverables, prepare a schedule of required tasks, identify issues and risks, confirm the product design proposal with stakeholders and customers).
Learning outcome 3: Know how to prepare a final product design solution

3A Product design solution
• Information required to develop design solutions to satisfy design proposals:
  ○ design criteria, e.g. design alternatives, cost analysis, processing/manufacturing, product life cycle, sustainability, materials, safety, finishes
  ○ constraints, e.g. social, health and safety, legal, economic, environmental, ethics, manufacturing capacity, cost, tooling, access to parts and raw materials, expertise of labour force.
3B Selection of final product design solution
• Selection criteria, e.g. product quality, product cost, customer satisfaction, overall manufacturability.

What needs to be learned
Learning outcome 4: Understand how to evaluate a final product design solution

4A Methods of evaluation to test selected design solutions
• Testing procedures to evaluate product performance in a controlled and working environment:
  ○ gather test data, e.g. security test data, black box test data, performance data, and analyse results against established criteria
  ○ complete a tolerance analysis
  ○ identify product shortcomings and establish any need for redesign work.

Essential information for tutors and assessors

Essential resources

There are no special resources needed for this unit.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners identify a product design specification for an ongoing fabrication activity in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. The product design specification must have enough scope for learners to describe at least **five** content items. Learners will:

1. describe at least **five** content items of the product design specification they have identified including the purpose of the item and the type of content it includes (AC1.1)
2. describe the key activities involved in the preparation of the identified product design specification. Learners must include details of the purpose of the activity and how to carry it out (AC1.2).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners identify a product design proposal for an ongoing fabrication activity in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe at least **five** content items of the product design proposal they have identified, including the type of content included in each item and its purpose (AC2.1)
2. describe the key stages involved in the preparation of a product design proposal. Learners must include details of the actions involved in and the purpose of each stage (AC2.2, 2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners review a product design solution for a completed product or assembly in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe at least **three** design criteria and **three** constraints that influenced the design of the product or assembly. Learners must provide examples of how the criteria and constraints influenced the design (AC3.1)
2. explain the criteria influencing the selection of the final product solution. Learners must give reasons for how the criteria can influence the selection of the final product solution (AC3.2).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners evaluate a given product design solution for the completion of a product or assembly in in their own organisation or, if they are not in employment, in an engineering organisation with which they are familiar. Learners will:

1. describe at least **four** testing methods that can be used to evaluate a final product design solution for a selected product or assembly (AC4.1)
2. describe the type of test data used during the evaluation of a final product design solution, including how it was gathered (AC4.2)
3. evaluate the final product design solution, referring to the data results and making recommendations for changes to the design if appropriate. Learners must draw together and review all information shown by the data results and reach a conclusion. (AC4.3).

Unit 19: Additive Manufacturing (3D Printing)

Level:	**2**
Unit type:	**Optional**
Assessment type:	**Internal**
Guided learning hours:	**50**

Unit introduction

Three-dimensional (3D) printing or additive manufacturing is a technology in which material is joined or solidified to produce components used in engineering. It involves converting a digital (CAD) model into a physical three-dimensional object by adding material onto a build platform a layer at a time. A number of different technologies are available to complete 3D printing, using materials such as metals, plastic and paper. Once printed, a component is usually subject to some post-processing, such as painting or varnishing, to finish it off.

In this unit, you will gain an understanding of the main principles of 3D printing and you will be introduced to typical 3D printing technology. You will explore common applications for 3D printing in industry and learn about the structural and electronic components used in 3D printers. You will learn how to complete preventative maintenance for a 3D printer so that the printer is maintained in useable condition. Finally, you will learn how to use 3D printers, studying the materials used in printing, and how to finish/complete a printed component.

Learning outcomes and assessment criteria

To pass this unit, the learner needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria determine the standard required to achieve the unit.

Learning outcomes		Assessment criteria	
1	Understand the principles and application of 3D printing technology	1.1	Explain the main principles of 3D printing technology
		1.2	Describe typical processes for undertaking 3D printing
		1.3	Describe common applications for 3D printing technology
		1.4	Describe preventative maintenance operations to be performed to maintain 3D printers in useable condition
2	Know how to prepare 3D printing technology	2.1	Describe the key structural components of 3D printing technology
		2.2	Describe the main electronic elements of 3D printing technology
3	Know how to use 3D printing technology	3.1	Describe the technology used to undertake 3D printing
		3.2	Describe the materials used to undertake 3D printing
		3.3	Describe how to set up and use a 3D printer
		3.4	Describe how to complete or finish a 3D printed element

Unit content

What needs to be learned
Learning outcome 1: Understand the principles and application of 3D printing technology
1A Principles • Digital design, computer aided design (CAD) environment, extruding processes, imported geometry, meshes, scanning tools, moving and aligning parts, joints, fasteners, finishes. **1B Processes** • Extrusion, direct energy deposition, solidification of power, photo-polymerisation, sheet lamination, direct metal laser sintering (DMLS), indirect metal printing. **1C Application** • Industry: product components, spare parts, reproduction of parts, drones, complex products, prototypes, low volume complex components, reverse engineering. • Health: dental bridges and crowns, prostheses. • Space technology, complex one-off components. **1D Maintenance** • Lubrication of moving parts, clean filament nozzle, clean extruder gear, replace Kapton® tape, replace build surface area, update 3D printer firmware. • Metal printing equipment, specialised maintenance, e.g. laser print head.
Learning outcome 2: Know how to prepare 3D printing technology
2A Structural components • Frame, X, Y and Z motion, extruder, motor, position sensors, power supply, nozzle, filament feeder. **2B Electronic elements** • RAMPS, RAMBo, Sanguinololu, Minitronics, RUMBA, Elefu RA V3, Megatronics, firmware, wiring.

What needs to be learned
Learning outcome 3: Know how to use 3D printing technology
3A Technology • Fused deposition modelling, electron beam direct manufacturing, selected laser sintering, 3D printing, stereolithography, polyjet process, laminated object manufacturing. **3B Material** • Polymer filament, e.g. Acrylonitrile Butadiene Styrene (ABS), bio-based filament, e.g. polylactic acid (PLA) plastic metals, ceramics, photocurable resins, paper. • Metal powders, e.g. steel, aluminium, titanium. **3C Printing process** • CAD design, interface to printer, set up filament, bed preparation, build up model layers, post-processing and finishing model. **3D Finishing** • Filling, priming, sanding, tumbling, painting, e.g. undercoat and top coat, vapour polishing, support structures.

Essential information for tutors and assessors

Essential resources

For this unit, centres need access to a workshop with low-cost polymer printers.

Assessment

This section must be read in conjunction with *Section 8 Assessment*.

This unit is internally assessed. To pass this unit, the evidence that learners present for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.

The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way. It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. This engineering workplace can either be their own employer or another single engineering organisation with which they are familiar.

A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a feasibility report for the purchase of a new 3D printer to be used in their own organisation to manufacture components or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. annotate a diagram provided by the tutor to outline the key principles by which 3D printing is performed (AC1.1)
2. give a clear account of at least **three** different processes for undertaking 3D printing (AC1.2)
3. outline **three** applications for which 3D printing technology is used. These applications should be related to the workplace where possible (AC1.3)
4. give a clear account of the preventative maintenance operations to be performed to keep the chosen 3D printer in serviceable condition (AC1.4).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an annotated diagram of the key structural components of a 3D printer to be used in their own organisation or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. give details of least **four** key structural components, including the purpose of each component (AC2.1)
2. give details of **four** electronic components, including the purpose of each component (AC2.2).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners produce a guidance document for the use of a 3D printer in their own organisation or, if they are not in employment, in an organisation with which they are familiar. Learners will:

1. illustrate in the guidance document at least **four** types of 3D printing technology that can be used to print a component, using annotated sketches to provide a clear account of each 3D printing technology (AC3.1)
2. outline at least **three** materials that might be used to print a component, including the main characteristics of each material (AC3.2)
3. fully describe the set-up and stages of use of a 3D printer (AC3.3)
4. describe at least **four** techniques used after printing to finish a printed element, including the details of the purpose of each technique and actions required (AC3.4).

10 Suggested teaching resources

This section lists resource materials that can be used to support the delivery of the qualifications.

Textbooks

Adams J – *Electrical Safety: A Guide to the Causes and Prevention of Electrical Hazards* (Institution of Electrical Engineers, 1994) ISBN 9780852968062

Askeland D – *Science and Engineering of Materials* (Wandsworth Publishing, 2010) ISBN 978-0495296027

Bird J – *Basic Engineering Mathematics* (Routledge, 2017) ISBN 978-1138673700

Bird J O – *Electrical and Electronic Principles and Technology* (Routledge, 2017) ISBN 978-1138673526

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Websites

www.freestudy.co.uk	Engineering Council – open learning tutorials
http://freecircuitdiagrams4u.blogspot.co.uk/	Example circuit diagrams for various devices
http://www.freecadweb.org/	Website for free CAD software resources (FreeCAD)
www.study.com/	A series of videos giving information on some of the skills and personal requirements of engineering operatives.

11 Appeals

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

Centres must document all learners' appeals and their resolutions. Further information on the appeals process can be found in the document *Internal assessment in vocational qualifications: Reviews and appeals policy*, available on our website.

12 Malpractice

Dealing with malpractice in assessment

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

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

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

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

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

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

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

Learner malpractice

The head of centre is required to report incidents of suspected learner malpractice that occur during Pearson qualifications. We ask centres to complete Joint Council for Qualifications (JCQ) *Form M1* (www.jcq.org.uk/exams-office/malpractice) and email it with any accompanying documents (signed statements from the learner, invigilator, copies of evidence, etc.) to the Investigations Processing team at candidatemalpractice@pearson.com. The responsibility for determining appropriate sanctions or penalties to be imposed on learners lies with Pearson.

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

Failure to report malpractice constitutes staff or centre malpractice.

Teacher/centre malpractice

The head of centre is required to inform Pearson's Investigations team of any incident of suspected malpractice (which includes maladministration) by centre staff, before any investigation is undertaken. The head of centre is requested to inform the Investigations team by submitting a *JCQ M2* Form (www.jcq.org.uk/exams-office/malpractice) with supporting documentation to pqsmalpractice@pearson.com. Where Pearson receives allegations of malpractice from other sources (for example Pearson staff, anonymous informants), the Investigations team will conduct the investigation directly or may ask the head of centre to assist.

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

We reserve the right to withhold certification when undertaking investigations, audits and quality assurance processes. You will be notified within a reasonable period of time if this occurs.

Sanctions and appeals

Where malpractice is proven, we may impose sanctions or penalties, such as:

- mark reduction for affected external assessments
- disqualification from the qualification
- debarment from registration for Pearson qualifications for a period of time.

If we are concerned about your centre's quality procedures, we may impose sanctions such as:

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

The centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from the head of centre (on behalf of learners and/or members or staff) and from individual members (in respect of a decision taken against them personally). Further information on appeals can be found in the JCQ appeals booklet: *A guide to the awarding bodies' appeals process.*

13 Further information and publications

- Edexcel, BTEC and Pearson Work Based Learning contact details: qualifications.pearson.com/en/support/contact-us.html.
- Books, software and online resources for UK schools and colleges: www.pearsonschoolsandfecolleges.co.uk.
- Our publications catalogue lists all the material available to support our qualifications. To access the catalogue and order publications, please visit our website.

All centres offering external assessments must comply with the Joint Council for Qualifications (JCQ) document *Instructions for conducting examinations*.

Further documents that support the information in this specification:

- *Access arrangements and reasonable adjustments (JCQ)*
- *A guide to the special consideration process (JCQ)*
- *Collaborative and consortium arrangements for the delivery of vocational qualifications policy (Pearson)*
- *UK information manual* (updated annually and available in hard copy) **or** E*ntries and information manual* (available online) (Pearson)
- Distance learning and assessment policy (Pearson).

Publisher information

Any publisher can seek endorsement for their resources and, if they are successful, we will list their BTEC resources on our website.

14 Glossary

Part A – General terminology used in specification

Level	Units and qualifications have a level assigned to them. The level assigned is informed by the level descriptors defined by Ofqual, the qualifications regulator.
Guided learning hours (GLH)	This indicates the number of hours of activities that directly or immediately involve tutors and assessors in teaching, supervising, and invigilating learners, for example lectures, tutorials, online instruction and supervised study. Units may vary in size.
Total qualification time (TQT)	This indicates the total number of hours that a typical learner will take to complete the qualification. This is in terms of both guided learning hours but also unguided learning, for example private study, time spent in the workplace to master skills.
Learning outcomes	The learning outcomes of a unit set out what a learner knows, understands or is able to do as the result of a process of learning.
Assessment criteria	The assessment criteria specify the standard the learner is required to meet to achieve a learning outcome.
Unit content	This section sets out the required teaching content of the unit and specifies the knowledge, skills and understanding required for achievement of the unit. It enables centres to design and deliver a programme of learning that will enable learners to achieve each learning outcome and to meet the standard determined by the assessment criteria.
Summative assessment	Assessment that takes place after the programme of learning has taken place.
Valid assessment	The assessment assesses the skills or knowledge/understanding in the most sensible, direct way to measure what it is intended to measure.
Reliable assessment	The assessment is consistent and the agreed approach delivers the correct results on different days for the same learners and different cohorts of learners.

Part B – Terms used in knowledge and understanding criteria

Define	Specify exactly the meaning, nature or scope of something. The use of correct terminology is expected.
Describe	Give a clear account in their own words, including all the relevant information (e.g. qualities, characteristics or events, etc.). Description shows recall and in some cases application.
Detailed	Having additional facts or information beyond a simple response.
Evaluate	Bring together all information and review it to form a supported conclusion, drawing on evidence, including strengths, weaknesses, alternative actions, relevant data or information.
Explain	Provide details and give reasons and/or evidence to support an opinion, view or argument. OR Provide details and give relevant examples to clarify and extend a point. This would usually be in the context of learners showing their understanding of a technical concept or principle.
Identify	Shows the main features or purpose of something. Can recognise it and/or name characteristics or facts that relate to it.
Outline	Provide a summary or overview or brief description.
Select	Choose the best or most suitable option whether this is of materials, techniques, equipment or processes. The options and choices should be based on specific criteria.
State	Express information in clear and precise terms.

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For information about Pearson qualifications, including Pearson Edexcel, BTEC and LCCI qualifications visit qualifications.pearson.com

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