Pearson
BTEC

Pearson
BTEC Level 3 Diploma in Machining (Development Knowledge)

Specification

BTEC Specialist qualification

First teaching September 2019

Issue 1

Edexcel, BTEC and LCCI qualifications

Edexcel, BTEC and LCCI qualifications are awarded by Pearson, the UK's largest awarding body offering academic and vocational qualifications that are globally recognised and benchmarked. For further information, please visit our qualification website at qualifications.pearson.com. Alternatively, you can get in touch with us using the details on our contact us page at qualifications.pearson.com/contactus

About Pearson

Pearson is the world's leading learning company, with 35,000 employees in more than 70 countries working to help people of all ages to make measurable progress in their lives through learning. We put the learner at the centre of everything we do, because wherever learning flourishes, so do people. Find out more about how we can help you and your learners at qualifications.pearson.com

ISBN 978 1 446 96315 9

Contents

1 Introducing BTEC Specialist qualifications

What are BTEC Specialist qualifications?

BTEC Specialist qualifications are work-related qualifications available from Entry level to Level 3 in a range of sectors. They give learners the knowledge, understanding and skills they need to prepare for employment in a specific occupational area. The qualifications also provide career development opportunities for those already in work.

BTEC Specialist qualifications put learning into the context of the world of work, giving learners the opportunity to apply their research, skills and knowledge in relevant and realistic work contexts. This applied, practical approach means learners develop the knowledge, understanding and skills they need for career progression or further study. As such, these qualifications are well-suited to support the delivery of the Apprenticeship Standards.

The qualifications may be offered as full-time or part-time courses in schools, colleges, training centres and through employers.

Sizes of BTEC Specialist qualifications

For all regulated qualifications, Pearson specifies a total estimated number of hours that learners will require to complete and show achievement for the qualification – this is the Total Qualification Time (TQT). The TQT value indicates the size of a qualification.

Within the TQT, Pearson identifies the number of Guided Learning Hours (GLH) that we estimate a centre delivering the qualification might provide. Guided learning means activities, such as lessons, tutorials, online instruction, supervised study and giving feedback on performance, that directly involve tutors and assessors in teaching, supervising and invigilating learners. Guided learning includes the time required for learners to complete external assessment under examination or supervised conditions.

In addition to guided learning, other required learning directed by tutors or assessors includes private study, preparation for assessment and undertaking assessment when not under supervision, such as preparatory reading, revision and independent research.

As well as TQT and GLH, qualifications can also have a credit value – equal to one tenth of the TQT, rounded to the nearest whole number.

TQT and credit values are assigned after consultation with employers and training providers delivering the qualifications.

BTEC Specialist qualifications are generally available in the following sizes:

- Award – a qualification with a TQT value of 120 or less
  (equivalent to a range of 1–12 credits)
- Certificate – a qualification with a TQT value in the range of 121–369
  (equivalent to a range of 13–36 credits)
- Diploma – a qualification with a TQT value of 370 or more
  (equivalent to 37 credits and above).

2 Qualification summary and key information

Qualification title	**Pearson BTEC Level 3 Diploma in Machining (Development Knowledge)**
Qualification Number (QN)	603/5028/3
Regulation start date	01/09/2019
Operational start date	01/09/2019
Approved age ranges	16–18 19+ Please note that sector-specific requirements or regulations may prevent learners of a particular age from embarking on this qualification. Please see *Section 6 Access and recruitment*.
Total qualification time (TQT)	633
Guided learning hours (GLH)	480
Assessment	Internal assessment.
Grading information	The qualification and units are graded Pass/Merit/Distinction.
Entry requirements	For learners taking this qualification as a stand-alone qualification, no prior knowledge, understanding, skills or qualifications are required before registering for this qualification. However, Centres must also follow the information in our document, *A guide to recruiting with integrity and enrolling learners onto qualifications* which is available on the Support section of our website. Learners taking this qualification as part of the Level 3 Engineering Technician Apprenticeship must have achieved the Level 2 Diploma in Machining (Foundation Knowledge) before registering for this qualification.
Funding	Qualifications eligible and funded for post-16-year-olds can be found on the funding Hub. The Apprenticeship funding rules can be found at www.gov.uk

Centres will need to use the Qualification Number (QN) when they seek public funding for their learners. The qualification title, unit titles and QN will appear on each learner's final certificate. Centres should tell learners this when recruiting them and registering them with Pearson. There is more information about certification in our UK Information Manual, available on our website, qualifications.pearson.com

3 Qualification purpose

Qualification objectives

The Pearson BTEC Level 3 Diploma in Machining (Development Knowledge) is for learners working, or intending to work in an Engineering Technician job role. It is designed to support the off-the-job training and development of apprentices on the Engineering Technician apprenticeship programme (Advanced Manufacturing Machining pathway). It is also for those individuals not on an apprenticeship programme but who wish to achieve a qualification to prepare for employment.

The qualification gives learners the opportunity to:

- develop the technical knowledge and understanding that underpins competence in the stated job role
- learn about a range of transferable skills and professional attributes that support successful performance in the workplace
- achieve a nationally-recognised Level 3 qualification
- develop confidence and readiness for the apprenticeship end-point assessment.

Apprenticeships

The Level 3 Diploma in Machining (Development Knowledge) is a mandatory requirement within the Engineering Technician Apprenticeship Standard. Learners must achieve this qualification before progressing to the End-point Assessment.

Annexe 1 shows how the knowledge and behaviours from the apprenticeship standard are covered in the qualification.

Progression opportunities

Learners who achieve the qualification and also meet all other specified requirements of the Apprenticeship Standard can progress to achieving the full Apprenticeship certification that confirms competency in the Engineering Technician job role, as a Machinist in the Advanced Manufacturing sector.

Completion of the Engineering Technician Apprenticeship is designed to be recognised by relevant Professional Engineering Institutions at the appropriate level of professional registration (EngTech).

Industry support and recognition

The Pearson BTEC Level 3 Diploma in Machining (Development Knowledge) was developed through close collaboration with the Engineering Technician Trailblazer group, Semta, EAL and City and Guilds.

The trailblazer group included the following employers: Airbus Group Ltd, Babcock International Group, BAE Systems plc, BMW, British Airways, Cooper & Turner, Edward Pryor & Son Ltd, The Engineering Employer Federation, Gama Aviation Ltd, GKN Aerospace Ltd, GTA England Ltd, Harrods Aviation Ltd, The Institution of Engineering and Technology, Institution of Mechanical Engineers, Jaguar Land Rover, Leonardo Helicopters UK, Marshall Aerospace and Defence Group, MBDA (UK) Ltd, Mersey Maritime Group, Newburgh Precision, NFEC Ltd, Nikken Kosakusho Europe Ltd, Resource Group, Rolls-Royce plc, Royal Aeronautical Society, Royal Air Force Cosford, Royal Navy, Siemens plc, Toyota Motor Manufacturing (UK) Ltd, UTC Aerospace Systems.

4 Qualification structure

Pearson BTEC Level 3 Diploma in Machining (Development 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	8
Number of mandatory units that must be achieved	4
Number of optional units that must be achieved	4

Unit number	Mandatory units	Level	Guided Learning Hours
1	Health and Safety in the Engineering Workplace	3	60
2	Communications for Engineering Technicians	3	60
3	Mathematics for Engineering Technicians	3	60
4	Properties and Applications of Engineering Materials	3	60

Unit number	Optional units	Level	Guided Learning Hours
5	Advanced Manual Turning Techniques Barred combination with *Unit 7 Advanced Milling and Turning Techniques*	3	60
6	Advanced Manual Milling Techniques Barred combination with *Unit 7 Advanced Milling and Turning Techniques*	3	60

Unit number	Optional units	Level	Guided Learning Hours
7	Advanced Manual Milling and Turning Techniques Barred combination with unit *Unit 5: Advanced Manual Turning Techniques* and *Unit 6: Advanced Manual Milling Techniques*	3	60
8	CNC Programming	3	60
9	Advanced CNC Turning Techniques Barred combination with *Unit 11: Applications of Computer Numerical Control (CNC) in Engineering*	3	60
10	Advanced CNC Milling Techniques Barred combination with *Unit 11: Applications of Computer Numerical Control (CNC) in Engineering*	3	60
11	Applications of Computer Numerical Control (CNC) in Engineering Barred combination with *Unit 9: Advanced Manufacturing CNC Turning Techniques* and *Unit 10: Advanced Manufacturing CNC Milling Techniques*	3	60
12	Specialist Machining	3	60
13	Computer Aided Drafting in Engineering	3	60
14	Precision Grinding Techniques	3	60
15	Further Engineering Mathematics	3	60
16	Organisational Efficiency and Improvement	3	60
17	Engineering Inspection and Quality Control	3	60
18	Engineering Design Process	3	60

5 Centre resource requirements

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

General resource requirements

- Centres must have appropriate physical resources (for example IT, learning materials, teaching rooms) to support the delivery and assessment of the qualification.
- Staff involved in the assessment process must have relevant expertise and occupational experience. This includes having:
    - current (within the last three years) occupational experience appropriate to the level and breadth of subject areas of the qualification units being assessed
    - substantial knowledge and understanding of the subject areas appropriate to the level, breadth and content of the qualification units. This may be evidenced through having a relevant qualification that is at an equivalent or higher level than the level of the qualification being assessed
    - a relevant qualification in assessment and/or internal quality assurance or current (within the last three years) experience of assessing and/or internal verification appropriate and relevant to the level and subject area of the qualification units
    - evidence of continuing professional development (CPD) which may include the achievement of qualifications relevant to the areas being assessed.
- There must be systems in place that ensure continuing professional development (CPD) for staff delivering the qualification.
- Centres must have appropriate health and safety policies in place that relate to the use of equipment by learners.
- Centres must have in place robust internal verification systems and procedures to ensure the quality and authenticity of learners' work as well as the accuracy and consistency of assessment decisions between assessors operating at the centre. For information on the requirements for implementing assessment processes in centres, please refer to the *BTEC UK Quality Assurance Centre Handbook* available on our website.
- Centres must deliver the qualifications in accordance with current equality legislation. For further details on Pearson's commitment to the Equality Act 2010, please see *Section 6 Access and recruitment*. For full details of the Equality Act 2010 visit www.legislation.gov.uk

6 Access and recruitment

Our policy on access to our qualifications is that:

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

Centres must ensure that their learner recruitment process is conducted with integrity. This includes ensuring that applicants have appropriate information and advice about the qualification to ensure that it will meet their needs.

Centres should review applicants' prior qualifications and/or experience, considering whether this profile shows that they have the potential to achieve the qualification.

We refer Centres to the Pearson Equality, diversity and inclusion policy, which can be found in the support section of our website.

Prior knowledge, skills and understanding

Learners taking this qualification as a stand-alone qualification are required to have no prior knowledge, skills or understanding before registering for this qualification.

Learners taking this qualification as part of the Level 3 Engineering Technician Apprenticeship must have achieved the Level 2 Diploma in Machining (Foundation Knowledge) before registering for this qualification.

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 undertaking one of our qualifications, disadvantaged in comparison to learners who do not share that characteristic
- all learners achieve the recognition they deserve from undertaking a 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 qualification. Please see *Section 8 Assessment* for information on reasonable adjustments and special consideration.

7 Programme delivery

Centres are free to offer this qualification using any mode of delivery that meets learners' and employers' needs. It is recommended that centres make use of a wide range of training delivery methods, including direct instruction in classrooms, simulated demonstrations, research or applied projects, e-learning, directed self-study, field visits and role play. Whichever mode of delivery is used, centres must make sure that learners have access to the resources identified in the specification and to the subject specialists delivering the units.

Centres must adhere to the Pearson policies that apply to the different models of delivery. Our document, *Collaborative and consortium arrangements for the delivery of vocational qualifications policy* is available on our website.

Those planning the programme should aim to enhance the vocational nature of the qualification by:

- spending time with employers to better understand their organisational requirements and the methods of training that are most suitable, taking into consideration their available resources and working patterns
- collaborating with employers to ensure that learners have opportunities in the workplace to implement the knowledge and skills developed through the training programme
- developing up-to-date and relevant teaching materials that make use of scenarios relevant to the sector and relevant occupation
- giving learners the opportunity to apply their learning in realistic practical activities
- having regular meetings with employers to discuss learner progress, providing feedback and agreeing how any issues will be resolved
- developing projects or assessments with input from employers
- using 'expert witness' reports from employers to support assessment
- making full use of the variety of experience of work and life that learners bring to the programme.

Where legislation is taught, centres must ensure that it is current and up to date.

For further information on the delivery and assessment of the Apprenticeships Standards please refer to document, *ESFA funding rules for further education provision* at: www.gov.uk/government/collections/sfa-funding-rules

8 Assessment

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

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

In administering internal assessments, centres need to be aware of the specific procedures and policies that apply to, for example, registration, entries and results. More information can be found in our *UK Information Manual*, available on our website.

Language of assessment

Assessments for internally-assessed units are in English only.

A learner taking the qualification 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* document, available on our website.

For further information on access arrangements, please refer to *Reasonable adjustments* later in this section.

Internal assessment

All units in these qualifications are internally assessed and subject to external standards verification. This means that centres set and mark the final summative assessment for each unit using the examples and support that Pearson provides. Centres need to be, if they are not already, approved to offer the qualifications before conducting assessments. *Section 10 Centre recognition and approval* gives information on approval for offering these qualifications.

Assessment through assignments

For internally-assessed units, the format of assessment is an assignment taken after the content of the unit, or part of the unit if several assignments are used, has been delivered. An assignment may take a variety of forms, including practical and written. An assignment is a distinct activity, completed independently by learners, that is separate from teaching, practice, exploration and other activities that learners complete with direction from tutors and assessors.

An assignment is issued to learners as an assignment brief with a defined start date, a completion date and clear requirements for the evidence that they need to provide.

Assignments can be divided into tasks and may require several forms of evidence. A valid assignment will enable there to be a clear and formal assessment outcome based on the assessment criteria.

Designing effective assignments

To ensure that final assessment decisions meet the required standard, assignments must be fit for purpose as a tool for measuring learning against the defined content and assessment criteria. Centres should make sure that assignments enable learners to produce valid, sufficient, authentic and appropriate evidence that relates directly to the specified criteria within the context of the learning outcomes and unit content.

An assignment that is fit for purpose and suitably controlled is one in which:

- the tasks that the learner is asked to complete provide evidence for a learning outcome that can be assessed using the assessment criteria
- the time allowed for the assignment is clearly defined and consistent with what is being assessed
- the centre has the required resources for all learners to complete the assignment fully and fairly
- the evidence the assignment will generate will be authentic and individual to the learner
- the evidence can be documented to show that the assessment and verification has been carried out correctly.

Recommended assignments are provided in the *Further information for tutors and assessors* section of each unit. In designing assignments, centres need to work within the structure of the recommended assignments. They need to consider the following points when developing their assignment briefs.

- Centres may choose to combine all or parts of different units into single assignments provided that all units and all their associated learning outcomes are fully addressed in the programme overall. If this approach is taken, centres need to make sure that learners are fully prepared so that they can provide all the required evidence for assessment, and that centres are able to track achievement in the records.
- A learning outcome must always be assessed as a whole and should not be split into two or more assignments.
- The assignment must be targeted to the learning outcomes but the learning outcomes and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.

- Centres do not have to follow the order of the learning outcomes of a unit in developing assignments but later learning outcomes often require learners to apply the content of earlier learning outcomes, and they may require learners to draw their learning together.
- Assignments must be structured to allow learners to demonstrate the full range of achievement at all grade levels. Learners need to be treated fairly by being given the opportunity to achieve a higher grade if they have the ability.
- As assignments provide the final assessment, they will draw on the specified range of teaching content for the learning outcomes. The specified content is compulsory for teaching and learning. The evidence for assessment need not cover every aspect of the teaching content as learners will normally be given particular examples, case studies or contexts in their assignments. For example, if a learner is carrying out research on their employer organisation, then they will address all the relevant range of content that applies in that instance.

Providing an assignment brief

A good assignment brief is one that, through providing challenging and realistic tasks, motivates learners to provide appropriate evidence of what they have learned. An assignment brief should include:

- a vocational scenario, context, or application for the tasks to be completed
- clear instructions to the learner about what they are required to do – normally set out through a series of tasks
- an audience or purpose for which the evidence is being provided.

Forms of evidence

Centres may use a variety of forms of evidence as long as they are suited to the type of learning outcome being assessed. For some units, the practical demonstration of skills is necessary and for others, learners will need to demonstrate their knowledge and understanding. The units give information on what would be suitable forms of evidence.

Centres may choose to use different suitable forms for evidence to those proposed. Overall, learners should be assessed using varied forms of evidence.

Some of the forms of evidence include:

- written tasks or reports
- projects
- sketchbooks, work logbooks, reflective journals, workbooks
- presentations with assessor questioning

The form(s) of evidence selected must:

- allow the learner to provide all the evidence required for the learning outcomes and the associated assessment criteria
- allow the learner to produce evidence that is their own independent work
- allow a verifier to independently reassess the learner to check the assessor's decisions.

For example, when using performance evidence, centres need to think about how supporting evidence can be captured through preparation notes, reflective accounts, logbook records, recordings, photographs or task sheets.

Centres need to take particular care that learners are enabled to produce independent work. For example, if learners are asked to use real examples, then best practice would be to encourage them to use examples of their own experiences.

For information on the requirements for implementing assessment processes in centres, please refer to the *BTEC UK Quality Assurance Centre Handbook* on our website.

Making valid assessment decisions

Authenticity of learner work

An assessor must assess only work that is authentic, i.e. learners' own independent work. Learners must authenticate the evidence that they provide for assessment through signing a declaration stating that it is their own work.

Assessors must ensure that evidence is authentic to a learner through setting valid assignments and supervising learners during assessment period. Assessors must take care not to provide direct input, instructions or specific feedback that may compromise authenticity.

Assessors must complete a declaration that:

- the evidence submitted for this assignment is the learner's own
- the learner has clearly referenced any sources used in the work
- they understand that false declaration is a form of malpractice.

Centres may use Pearson templates or their own templates to document authentication.

During assessment, an assessor may suspect that some or all of the evidence from a learner is not authentic. The assessor must then take appropriate action using the centre's policies for malpractice. More information is given later in this section.

Making assessment decisions using unit-based criteria

Assessment decisions for the qualification are based on the specific criteria given in each unit and set at each grade level. The assessment criteria for a unit are hierarchical and holistic. For example, if an M criterion requires the learner to show 'analysis' and the related P criterion requires the learner to 'explain', then to satisfy the M criterion a learner will need to cover both 'explain' and 'analyse'. The unit assessment grid shows the relationships between the criteria so that assessors can apply all the criteria to the learner's evidence at the same time.

Assessors make judgements using the assessment criteria and must show how they have reached their decisions in the assessment records. The assessor needs to make a judgement against each criterion that evidence is present and sufficiently comprehensive.

For example, the inclusion of a concluding section may be insufficient to satisfy a criterion requiring 'evaluation'.

Assessors should use the following information and support in reaching assessment decisions:

- the *Essential information for tutors and assessors* section of each unit, which gives further information on the requirements to meet the assessment criteria
- the centre's Lead Internal Verifier and assessment team's collective experience supported by the information provided by Pearson.

When a learner has completed the assessment for a unit then the assessor will give an assessment outcome for the unit. This is given according to the highest level for which the learner is judged to have met all the criteria. Therefore:

- to achieve a Distinction, a learner must have satisfied all the Distinction criteria (and therefore the Pass and Merit criteria); these define outstanding performance across the unit as a whole
- to achieve a Merit, a learner must have satisfied all the Merit criteria (and therefore the Pass criteria) through high performance in each learning aim
- to achieve a Pass, a learner must have satisfied all the assessment criteria for the learning outcomes, showing appropriate coverage of the unit content and therefore attainment at the stated level of the qualification. The award of a Pass is a defined level of performance and cannot be given solely on the basis of a learner completing assignments. Learners who do not satisfy the assessment criteria for the units should be reported as Unclassified.

Dealing with late completion of assignments

Learners must have a clear understanding of the centre's policy on completing assignments by the stated deadlines. Learners may be given authorised extensions for legitimate reasons, such as illness at the time of submission, in line with centre policies.

For assessment to be fair, it is important that learners are all assessed in the same way and that some learners are not advantaged by having additional time or the opportunity to learn from others.

If a late completion is accepted, then the assignment should be assessed normally using the relevant assessment criteria.

Issuing assessment decisions and feedback

Once the assessor has completed the assessment process for an assignment, the outcome is a formal assessment decision. This is recorded formally and reported to learners.

The information given to the learner:

- must show the formal decision and how it has been reached, indicating how or where criteria have been met
- may show why attainment against criteria has not been demonstrated
- must not provide feedback on how to improve evidence
- must be validated by an Internal Verifier before it is given to the learner.

Resubmissions and retakes

Learners who do not successfully pass an assignment are allowed to resubmit evidence for the assignment or to retake another assignment. As a matter of best practice, it is recommended that centres apply the BTEC Firsts and Nationals retake and resubmission rules; however as these rules are not mandatory for BTEC Specialist programmes at Entry Level to Level 3 they do not need to be applied

Administrative arrangements for internal assessment

Records

Centres are required to retain records of assessment for each learner. Records should include assessments taken, decisions reached and any adjustments or appeals. Further information can be found in our *UK Information Manual.* We may ask to audit centre records, so they must be retained as specified.

Reasonable adjustments to assessments

Centres are able to make adjustments to assessments to take account of the needs of individual learners, in line with the guidance given in the Pearson document *Guidance for reasonable adjustment and special consideration in vocational internally assessed units* which can be found on the policy page of our website. In most instances, adjustments can be achieved by following the guidance, for example allowing the use of assistive technology or adjusting the format of the evidence.

We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. 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.

Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document *Access arrangements and reasonable adjustments* which can be found on the JCQ website (www.jcq.org.uk).

Special consideration

Centres must operate special consideration in line with the guidance given in the Pearson document *Supplementary guidance for reasonable adjustment and special consideration in vocational internally assessed units*. Special consideration may not be applicable in instances where:

- assessment requires the demonstration of practical competence
- criteria have to be met fully
- units/qualifications confer licence to practice.

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.

A separate application must be made for each learner. Certification claims must not be made until the outcome of the application has been received.

Further information on special consideration can be found in the Joint Council for Qualifications (JCQ) document *A guide to the special consideration process.*

Both of the documents mentioned above are on our website.

Appeals against assessment

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 *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy* available on our website.

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 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 our *Centre guidance: Dealing with malpractice and maladministration in vocational qualifications document*, available on our website.

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

Internal assessment

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. Our document *Centre guidance: Dealing with malpractice and maladministration in vocational qualifications* 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.

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 examinations. We ask centres to complete JCQ Form M1 (available at 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.

Teacher/centre malpractice

The head of centre is required to inform Pearson's Investigations team of any incident of suspected malpractice by centre staff, before any investigation is undertaken. The head of centre is requested to inform the Investigations team by submitting a JCQ Form M2(a) (available at www.jcq.org.uk/exams-office) 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.

Incidents of maladministration (errors in the delivery of Pearson qualifications that may affect the assessment of learners) should also be reported to the Investigations team using the same method.

Heads of centres/principals/chief executive officers or their nominees are required to inform learners and centre staff suspected of malpractice of their responsibilities and rights, please see section 6.15 of the Joint Council for Qualifications (JCQ) document *Suspected malpractice in examinations and assessments – Policies and procedures.*

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 assurances 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.

Where learner malpractice is evidenced, penalties may be imposed 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
- placing temporary blocks on the centre's certificates
- placing temporary blocks on registration of learners
- debarring staff members or the centre from delivering Pearson qualifications
- suspending or withdrawing centre approval status.

The centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from 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 our document *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy,* available on our website. In the initial stage of any aspect of malpractice, please notify the Investigations Team (via pqsmalpractice@pearson.com) who will inform you of the next steps.

9 Recognising prior learning and achievement

Recognition of Prior Learning

Recognition of Prior Learning (RPL) is a method of assessment that 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.

10 Centre recognition and approval

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.

Centres offering mandatory qualifications for the Apprenticeship Standards must be listed on the Skills Funding Agency’s Register of Training Organisations and have a contract to deliver these.

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.

11 Quality assurance of centres

Quality assurance is at the heart of vocational qualifications and apprenticeships.

The centre assesses BTEC specialist qualifications and will use quality assurance to make sure managers, internal verifiers and assessors are standardised and supported. This also ensures learners are given appropriate opportunities that lead to valid and accurate assessment outcomes.

Pearson uses external quality assurance processes to verify that assessment, internal quality assurance and evidence of achievement meet nationally defined standards.

Our processes enable us to recognise good practice, effectively manage risk and support centres to safeguard certification and quality standards.

Our Standards Verifiers provide advice and guidance to enable centres to hold accurate assessment records and assess learners appropriately, consistently and fairly.

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

- the centre will work with Pearson to ensure that their centre-wide quality assurance systems are in place, effective and reviewed annually
- Lead Internal Verifier accreditation – this involves online training and standardisation of Lead Internal Verifiers using our OSCA platform, accessed via Edexcel Online.

Please note that not all qualifications will include Lead Internal Verifier accreditation. Where this is the case, each year we will allocate a Standards Verifier to conduct postal sampling of internal verification and assessor decisions for the Principal Subject Area.

For further details, please see the *BTEC Centre Guide to Managing Quality*, available on our website.

12 Understanding the qualification grading

This section explains the rules that we apply in providing an overall qualification grade for each learner. The final grade awarded for a qualification represents a holistic performance across all of the qualification. As the qualification grade is an aggregate of the total performance, there is some element of compensation in that a higher performance in some units will be balanced by a lower outcome in others.

In the event that a learner achieves more than the required number of optional units, the mandatory units along with the optional units with the highest grades will be used to calculate the overall result, subject to the eligibility requirements for that particular qualification title.

Awarding and reporting for the qualification

The awarding and certification of the qualification will comply with the requirements of the Office of Qualifications and Examinations Regulation (Ofqual).

Units are assessed using a grading scale of Distinction, Merit, Pass and Unclassified. All mandatory and optional units contribute to the overall qualification grade.

To achieve any qualification grade learners must:

- achieve a Pass grade, or higher in all units within a valid combination, and
- achieve the minimum number of points at a grade threshold.

It is the responsibility of the centre to ensure that a correct unit combination is adhered to.

Calculation of the qualification grade

The table below shows the minimum thresholds for calculating each grade.
The table will be kept under review over the lifetime of the qualification. In the event of any change, centres will be informed before the start of teaching for the relevant cohort and an updated table will be issued on our website.

Points thresholds

P	36
M	52
D	74

Learners who do not meet the minimum requirements for a qualification grade to be awarded will be recorded as Unclassified (U) and will not be certificated. They may receive a Notification of Performance for individual units. Our Information manual (available on our website) gives more information.

Points available for units

The table below shows the number of points available for units. For each unit, points are allocated depending on the grade awarded.

	All units
U	0
Pass	6
Merit	10
Distinction	16

Claiming the qualification grade

Subject to eligibility, Pearson will automatically calculate the qualification grade for your learners when the internal unit grades are submitted and the qualification claim is made. Learners will be awarded qualification grades for achieving the sufficient number of points within the ranges shown in the applicable *Calculation of Qualification Grade* table.

To allow for a weaker performance in some units to be balanced by a stronger performance in others, there is an element of compensation built into the grading model.

Examples of grade calculations

Example 1: Achievement of a Diploma with a pass grade

Unit	GL	Grade	Points
1. Health and Safety in the Engineering Workplace	60	Pass	6
2. Communications for Engineering Technicians	60	Pass	6
3. Mathematics for Engineering Technicians	60	Merit	10
4. Properties and Applications of Engineering Materials	60	Pass	6
5. Advanced Manual Turning Techniques	60	Pass	6
6. Advanced Manual Milling Techniques	60	Pass	6
Totals	**360**	**Pass**	**40**

The learner has sufficient points for a P grade

Example 2: Achievement of a Diploma with a Merit grade

Unit	GL	Grade	Points
1. Health and Safety in the Engineering Workplace	60	Merit	10
2. Communications for Engineering Technicians	60	Pass	6
3. Mathematics for Engineering Technicians	60	Pass	6
4. Properties and Applications of Engineering Materials	60	Merit	10
5. Advanced Manual Turning Techniques	60	Merit	10
6. Advanced Manual Milling Techniques	60	Merit	10
Totals	**360**	**Merit**	**52**

The learner has met the 52 point threshold for Merit and has passed all units.

Example 3: Achievement of a Diploma with a Distinction grade

Unit	GL	Grade	Points
1. Health and Safety in the Engineering Workplace	60	Merit	10
2. Communications for Engineering Technicians	60	Distinction	16
3. Mathematics for Engineering Technicians	60	Pass	6
4. Properties and Applications of Engineering Materials	60	Distinction	16
5. Advanced Manual Turning Techniques	60	Distinction	16
6. Advanced Manual Milling Techniques	60	Distinction	16
Totals	**360**	**Distinction**	**80**

The learner has exceeded the 74 point threshold for Distinction and has passed all units.

Example 4: An unclassified result for a Diploma

Unit	GL	Grade	Points
1. Health and Safety in the Engineering Workplace	60	Merit	10
2. Communications for Engineering Technicians	60	Merit	10
3. Mathematics for Engineering Technicians	60	Unclassified	0
4. Properties and Applications of Engineering Materials	60	Pass	6
5. Advanced Manual Turning Techniques	60	Pass	6
6. Advanced Manual Milling Techniques	60	Pass	6
Totals	**360**	**Fail**	**38**

The learner has sufficient points for P (36) but has not passed all units. Hence, the grade is U.

13 Units

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

Units have the following sections.

Unit number

The number is in a sequence in the specification. Where a specification has more than one qualification, numbers may not be sequential for an individual qualification.

Unit title

This is the formal title of the unit that will appear on the learner's certificate.

Level

All units and qualifications have a level assigned to them. The level assigned is informed by the level descriptors defined by Ofqual, the qualifications regulator.

Unit type]

This says if the unit is mandatory or optional for the qualification. See *Section 4 Qualification structure* for full details.

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.

Pearson has consulted with users of the qualification and has assigned a number of hours to this activity for each unit.

Unit introduction

This is designed with learners in mind. It indicates why the unit is important, what will be learned and how the learning might be applied in the workplace.

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.

Each learning outcome has Pass and Merit criteria. Each assignment has at least one Distinction criterion.

Distinction criteria represent outstanding performance in the unit.

Unit content

This section sets out the required teaching content of the unit and specifies the knowledge 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.

Where it is designed to support apprenticeships, the unit content is informed by the knowledge and understanding requirements of the relevant Apprenticeship Standard.

Relationship between unit content and assessment criteria

Content is compulsory except when shown as 'e.g.'. Although it is not a requirement that all of the content is assessed, learners should be given the opportunity to cover it all.

Learners should be asked to complete summative assessment only after the teaching content for the unit or learning outcomes has been covered.

Legislation

Legislation cited in the units is current at time of publication. The most recent legislation should be taught and assessed internally.

Essential information for tutors and assessors

This section gives information to support delivery and the implementation of assessment. It contains the following subsections.

- *Essential* resources – lists any specialist resources needed to deliver the unit. The centre will be asked to make sure that these resources are in place when it seeks approval from Pearson to offer the qualification.

  Assessment – for internally-assessed units, it provides recommended assignments and suitable sources of evidence for each learning outcome. It also gives information about the standard and quality of evidence expected for learners to achieve the learning outcome and pass each assignment. It is important that the information is used carefully, alongside the assessment criteria.

Unit 1: Health and Safety in the Engineering Workplace

Level: 3

Unit type: Mandatory

Guided Learning Hours: 60

Unit introduction

The welfare of people working or operating in any manufacturing or engineering environment is of prime importance. All workers should carry out their work safely to minimise risks to their health and wellbeing. In fact, many organisations not only reduce risks and make improvements to the working environment, but also try to make their own working environment superior to others, making it a competitive aspect when recruiting staff.

Health and safety in the workplace is about measures designed to protect the health and safety of employees, visitors and the general public who may be affected by workplace activities. Safety measures are concerned with controlling and reducing risks to anyone who might be affected.

Health and safety is controlled largely by legislation and regulations, with the law being continually revised and updated. It is important that organisations are aware of these changes and keep up to date with developments.

This unit will give learners an understanding of hazards and risks associated with health, safety, welfare and the environment in an engineering workplace, the associated legislation and regulations, and of their roles in complying with the related legal obligations. During teaching and learning, learners will be required to undertake full risk assessments and to appreciate the significant risks encountered in the workplace and the measures taken to deal with them. They will study the principles of reporting and recording accidents and incidents, in a legal context.

Learning outcomes

In this unit you will:

1 Understand health and safety and environmental legislation and regulations

2 Know about hazards and risks in the workplace

3 Understand the methods used when reporting and recording accidents and incidents.

Content

What needs to be learned
Learning outcome 1: Understand health and safety and environmental legislation and regulations
• Key features of health and safety legislation and regulations: the general contents of legislation and regulations or other relevant international equivalents and how they are satisfied by safe systems of work/procedures, including: o Health and Safety at Work etc. Act 1974 – duties of employers, employees, Health and Safety Executive (HSE) and others, general prohibitions o Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013 (as amended) – duties of employers, self-employed and people in control of work premises (the Responsible Person) to report certain serious workplace accidents, occupational diseases and specified dangerous occurrences o Personal Protective Equipment (PPE) at Work Regulations 1992 (as amended) – appropriate if risk cannot be controlled in any other way, types, assessing suitable PPE given the hazard, supply, instructions/training, correct use, maintenance and storage o Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended) – identifying harmful substances, assessing risks of exposure, types of exposure, safety data sheets, using/checking/maintaining control measures/equipment, training/instruction/information o Manual Handling Operations Regulations (MHOR) 1992 (as amended) – avoid the need for manual handling, types of hazard, assess risk of injury when manual handling is required, control and reduce the risk of injury, training in use of techniques/mechanical aids. • Environmental legislation and regulations: o environmental legislation and EU directives: Environmental Protection Act 1990; Pollution Prevention and Control Act 1999; Clean Air Act 1993; Radioactive Substances Act 1993; Controlled Waste Regulations 2012; Controls on Dangerous Substances and Preparations Regulations 2006 o roles and responsibilities of relevant personnel: employers; employees; HSE, e.g. span of authority, right of inspection, guidance notes and booklets; others, e.g. subcontractors, public, suppliers, customers, visitors

What needs to be learned
Learning outcome 1: Understand health and safety and environmental legislation and regulations
• application of environmental management systems: ISO 14000 (family of standards, a management tool); environmental management (what an organisation does to minimise the harmful effects on the environment caused by its activities); ISO 14004 (guidelines on the elements of an environmental management system and its implementation, and examines principle issues involved); ISO 14001 (specifies the requirements for such an environmental management system).

What needs to be learned
Learning outcome 2: Know about hazards and risks in the workplace
• In the workplace: methods to identify hazards, e.g. statements, analysis of significant risks, prediction of results or outcomes of those risks, use of accident data, careful consideration of work methods/production plans, site/area inspections. • Working environment: consideration of the workplace and its potential for harm, e.g. confined spaces, working over water or at heights, electrical hazards, chemicals, noise. • Hazards that become risks: identification of trivial or significant risk; potential to cause harm; choosing appropriate control measures; electrical safety, e.g. identifying and controlling hazards, cause of injury, effects of electricity on the body, circuit overloading; mechanical safety, e.g. identifying and controlling hazards, cause of injury, rotating equipment, sharp edges; safety devices, e.g. residual current device (RCD), fuses, guards, fail safe, sensors. • Risk assessments: items/area to be assessed, e.g. machine operation, work area; five steps (principal hazards, who is likely to be injured/harmed, evaluation of the risks and decisions on adequacy of precautions, recording findings, review assessment). • Use of control measures: e.g. removing need (design out), use of recognised procedures, substances control, guarding, lifting assessments and manual handling assessments, regular inspection, use of PPE, training of personnel, other personal procedures for health, safety and welfare. • Application of aids to lift or move loads: e.g. pinch bars, rollers, skates, pallet trucks, scissor lifts, forklift trucks, wall and overhead cranes; ancillary equipment, e.g. block and tackle, pull lifts, slings (chain, rope, polyester), shortening clutches, lifting/plate clamps, eye bolts (dynamo, collar), shackles (dee, bow.) • Regulations: e.g. Provision and Use of Workplace Equipment Regulations (PUWER) 1998, Lifting Operations and Lifting Equipment Regulations (LOLER) 1998. • Procedures: safe working load (SWL) capacity of equipment; 1200 maximum spread on slings when lifting; ensuring clearway and not moving loads over others' heads; not transporting people on loads; correct hand signals from floor staff to crane drivers; protection of chains and slings from sharp corners; setting hooks and sling/chain lengths correctly. • Storage of gases, oil, acids, adhesives and engineering materials: COSHH regulations; structure of storage buildings, stillages and shelving; control of ventilation, extraction and temperature; good housekeeping and stock management; storage of flammable liquids/compressed gases, oil, acids and adhesives.

What needs to be learned
Learning outcome 3: Understand the methods used when reporting and recording accidents and incidents
• Principles: why employers keep records of serious accidents, incidents and emergencies; responsibilities of competent persons; cost of accidents, e.g. direct, indirect, human consequences; trends, e.g. major causes, fatal and serious injury, methods of classification, statistics. • Recording and reporting procedures: regulations on accident recording and reporting, e.g. RIDDOR 2013, accident book, company procedures; procedures to deal with near misses or dangerous occurrences.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand health and safety and environmental legislation and regulations		
P1 explain the key features of relevant health and safety legislation and regulations as applied to an engineering environment	M1 assess the key features of relevant health and safety legislation and regulations in an engineering environment	D1 evaluate the extent to which legislation and regulations maintain health and safety in an engineering environment
P2 describe the roles and responsibilities of relevant personnel under current health and safety legislation and regulations in an engineering environment		
P3 explain the key features of the relevant legislation and EU directives, with regard to environmental management	M2 analyse the role of relevant personnel and management in maintaining legislation and EU directives relating to environmental management in an engineering environment	
P4 explain the requirements for the safe disposal of waste		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 2: Know about hazards and risks in the workplace		
P5 describe methods for identifying hazards in an engineering environment	M3 assess the effectiveness of control measures and procedures for safe working in minimising hazards and risks in an engineering environment	D2 justify the control measures and procedures used to deal with hazards and risks in accordance with workplace policies and legal requirements
P6 explain the control measures used to minimise hazards and risks in an engineering environment.		
P7 explain the procedures for safe working including moving different loads and storage of gas, oil, acids, adhesives and engineering materials in an engineering environment		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand the methods used when reporting and recording accidents and incidents		
P8 explain the principles that underpin reporting and recording accidents and incidents		
P9 explain the procedures used to record and report accidents, dangerous occurrences or near misses.	M4 assess the effectiveness of procedures used to record and report accidents, dangerous occurrences and near misses in an engineering environment	D3 evaluate the importance to the engineering environment of recording and reporting accidents and dangerous occurrences.

Essential information for tutors and assessors

Resources

For this unit learners must have access to:

- a wide range of safety literature.
- health and safety legislation and learning materials, including the website of the Health and Safety Executive: https://www.hse.gov.uk/.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand health and safety and environmental legislation and regulations	A written activity requiring learners to consider the key features of relevant health and safety and environmental legislation and regulations and to review the roles and responsibilities of management and other relevant personnel in the workplace.
2 Know about hazards and risks in the workplace	A report that considers the methods used to recognise and deal with hazards and how effective control measures and procedures for safe working are used to minimise them.
3 Understand the methods used when reporting and recording accidents and incidents	A written activity requiring learners to consider the principles of and procedures for the reporting of accidents, incidents and near misses.

Evidence of meeting the criteria can be collected from case studies, assignments and projects. These should enable learners to explore the application of legislation and regulations, and hazards and risks in the workplace.

The Pass grade specifies the minimum acceptable level required by learners. Assessment will need to cover all the learning outcomes but not necessarily all the topics included in the unit content. Achievement of a Merit or a Distinction grade will require answers that demonstrate additional depth and/or breadth of treatment.

Learning outcome 1 Understand health and safety legislation and regulations

To meet this learning outcome learners will complete written tasks. The organisation selected must be the learners' place of work, or if learners are not currently in employment, an organisation with which they are familiar. The assignment for this learning outcome will cover legislation and regulations. It is not expected that all the legislation and regulations listed in the content are covered, just those applicable to the given context.

For Distinction standard, learners will give a reasoned and balanced evaluation of the impact that health and safety legislation and regulations have on the engineering environment chosen. Learners will draw together information on the legislation and regulations that the organisation must follow to maintain health and safety for engineering operations. They will include detailed examples of the consequences of not following the legislation and regulations. They will reach justified conclusions on the importance of the legislation and regulations, for example, by considering what a machining area or cell may look like and how it may operate if the necessary legislation and regulations were not being followed. (D1)

For Merit standard, learners thoroughly assess the impact of health and safety legislation and regulations on the engineering environment in relation to engineering operations. They will give detailed reasons for applying the legislation and regulations and detailed examples of the consequences if they were not being followed, for example, by considering the impact on shop floor operators. (M1)

Learners will give a thorough analysis of the role of relevant personnel and management in maintaining legislation and EU directives relating to environmental management. Learners must consider the roles of employers and management and employees in relation to the engineering environment. Learners will support their work with detailed examples of the actions for which each role is responsible in an engineering environment, for example in relation to the use and disposal of oil-based cutting fluids. (M2)

For Pass standard, learners will provide details of the key features of the Health and Safety at Work etc Act 1974 and three health and safety regulations as applied to the engineering environment chosen. Learners must provide clear reasons why each of the key features is necessary in the engineering organisation. (P1)

Learners will give a clear account of the roles and responsibilities, in relation to health and safety legislation and regulations, of relevant personnel in the engineering environment (in the organisation). Learners will include the roles and responsibilities of employers and management, employees and others such as sub-contractors and visitors. (P2)

Learners will give details of the key features of the Environmental Protection Act 1990 and two environmental management EU directives as applied to the engineering environment chosen. Learners must give clear reasons why each of the key features is necessary in the engineering organisation. (P3)

Learners will give a clear account of the requirements for the safe disposal of waste in the engineering environment chosen, with clear reasons for these requirements and examples of what could happen if the requirements are not met. (P4)

Learning outcome 2 Know about hazards and risks in the workplace

To meet this learning outcome learners will identify hazards and control measures within the engineering environment, or if they are not in employment, within an engineering environment with which they are familiar. This could be based on a practical activity undertaken during teaching and learning to produce a risk assessment on an item or area in the engineering environment. The selected item and/or area should have a range of hazards and control measures, for example a centre lathe and the surrounding workspace.

Learners will also consider the movement of loads and the safe storage of gases, oil, acids, adhesives and other engineering materials.

For Distinction standard, learners will draw on their assessment evidence related to methods for identifying hazards and support it with detailed and justified reasons to show how the control measures and procedures used are appropriate to deal with hazards in a contextual situation, for example when new equipment has been installed. Learners will include consideration of other control measures that could be used and justified reasons for why they are not suitable in accordance with workplace policies and legal requirements. Learners will reach a justified and logical conclusion, for example by giving reasons why the use of accident data may not be relevant to identify hazards when new equipment has been installed. (D2)

For Merit standard, learners will give details of ways to control risks that result from the identified hazards. They will consider the different control measures and procedures that could be used to control the risks, with reference to the hierarchy of hazard controls, and give detailed valid reasons for their recommendations, for example by considering whether large protective safety screens (an engineering control) would be more effective than safety glasses (personal protective equipment) in certain situations (M3).

For Pass standard, learners will give a clear account of three methods used to identify hazards in an engineering environment, for example accident data, analysis of work methods/production plans and site/area inspections (P5).

Learners will give an overview of suitable control measures for six hazards identified in the engineering environment (item and/or area), with accurate details of two reasons for each control measure used (P6).

Learners will describe the correct procedures for moving two different loads correctly and safely in the engineering environment, including all stages of the process. One load should be moved manually (for example, a lathe chuck), and one load will need to be moved using equipment (for example, a large piece of plate).

Learners will also describe the correct precautions to be taken when storing the following in the engineering environment:

- gases (for example, compressed air)
- oil (for example, coolant)
- acids (for example, hydrochloric)
- adhesives (for example, epoxy resins)
- engineering materials (for example, bar/plate/billets). (P7)

Learners will need to include all relevant considerations for each.

Learning outcome 3 Understand the methods used when reporting and recording accidents and incidents

To achieve this learning outcome, learners investigate the types of accidents and incidents that could occur in the engineering environment and the procedures/methods in place to record and report accidents and incidents. Learners not in employment will base their evidence on an engineering environment with which they are familiar.

For Distinction standard, learners will provide a reasoned and balanced evaluation of the importance of the accident reporting and recording procedures in place in the engineering environment. They will draw on their evidence to reach conclusions about the importance of the procedures and provide relevant reasons to support their judgements, for example by using a case study to show how RIDDOR could be used to reduce accidents, dangerous occurrences and near misses in a large engineering workshop. (D3)

For Merit standard, learners consider all the procedures in place to record accidents, dangerous occurrences and near misses in the engineering environment. They will give detailed reasons for the procedures and examples of how they are used in the engineering environment. Learners will reach a judgement on the effectiveness of these procedures, for example by reviewing the documentation currently in place and whether it satisfies the requirements of RIDDOR.(M4)

For Pass standard, learners will give a clear rationale for the range of principles that support the requirement to report and record accidents and incidents in the engineering environment. (P8)

They will give a clear account of the procedures used in the workplace to record and report accidents, dangerous occurrences and near misses with clear reasons why they are used in the engineering environment. Learners must provide accurate references to RIDDOR in their response. (P9)

Unit 2: Communication for Engineering Technicians

Level: 3

Unit type: Mandatory

Guided Learning Hours: 60

Unit introduction

The ability to communicate effectively is an essential skill in all aspects of life. The usual methods of communication – speaking, reading and writing – receive considerable attention and learning time in all education stages. For engineers, these skills are important but come with complications – with the need to also convey technical information such as scale, perspective and standards of working.

The drive towards greater use of information and communication technology (ICT) is very much a part of modern life and is certainly the case for engineering. The engineering industry is in the front line of working towards paperless communication methods, for example the electronic transfer of data from the concept designer straight to the point of manufacture.

This unit will give learners a foundation for employment in a wide range of engineering disciplines (for example manufacturing, maintenance, communications technology), as well as providing a foundation for further study. The aim of the unit is to develop learners' ability to communicate using a diverse range of methods. These include visual methods, such as drawing and sketching, and computer-based methods, such as two-dimensional (2D) computer-aided design (CAD) and graphical illustration packages. The unit will also develop learners' ability to write and speak in a framework of technology-based activities, using relevant and accurate technical language appropriate to the task and the audience.

The unit will introduce learners to a variety of skills and techniques to obtain and use information, for example the presentation of technical reports, business and technical data and the use of visual aids for presentations. Learners will consider how to make best use of ICT in technological settings that are relevant to their programme of study or area of employment.

Learning outcomes

In this unit you will:

1 Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information

2 Be able to use verbal and written communication skills in engineering settings

3 Be able to obtain and use engineering information

4 Be able to use information and communication technology (ICT) to present information in engineering settings.

Content

What needs to be learned
Learning outcome 1: Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information

• Interpret: obtain information and describe features, e.g:
  o component features, dimensions and tolerances, surface finish
  o identify manufacturing/assembly/process instructions, e.g. cutting lists, assembly arrangements, plant/process layout or operating procedures, electrical/electronic/communication circuit requirements
  o graphical information used to aid understanding of written or verbal communication, e.g. illustrations, technical diagrams, sketches.
• Engineering sketches/circuit/network diagrams: freehand sketches of engineering arrangements using 2D and 3D techniques, e.g:
  o components, engineering plant or equipment layout, designs or installations
  o electrical/ electronic circuit diagrams, system/network diagrams.
• Use of common drawing/circuit/network diagram conventions and standards, e.g. layout and presentation, line types, hatching, dimensions and tolerances, surface finish, symbols, parts lists, circuit/component symbols, use of appropriate standards (British (BSI), International (ISO)).

Learning outcome 2: Be able to use verbal and written communication skills in engineering settings

• Written work:
  o note taking, e.g lists, mind mapping/flow diagrams
  o writing style, e.g. business letter, memo writing, report styles and format, email, fax
  o proofreading and amending text
  o use of diary/logbook for planning and prioritising work schedules
  o graphical presentation techniques, e.g. use of graphs, charts and diagrams.
• Verbal methods:
  o speaking, e.g. with peers, supervisors, use of appropriate technical language, tone and manner
  o listening, e.g. use of paraphrasing and note taking to clarify meaning; impact and use of body language in verbal communication.

What needs to be learned
Learning outcome 3: Be able to obtain and use engineering information
• Information sources: ○ non-computer-based sources, e.g. books, technical reports, institute and trade journals, data sheets and test/experimental results data, manufacturers' catalogues ○ computer-based sources, e.g. inter/intranet, DVD-based information (manuals, data, analytical software, manufacturers' catalogues), spreadsheets, databases. • Use of information: e.g for the solution of engineering problems, for product/service/topic research, gathering data or material to support own work, checking validity of own work/findings.
Learning outcome 4: Be able to use information and communication technology (ICT) to present information in engineering settings.
• Software packages: ○ word processing; drawing, e.g. 2D CAD, graphics package ○ data handling and processing e.g. database, spreadsheet, presentation package, simulation package such as electrical/electronic circuits, plant/process systems ○ communication, e.g. email, fax, inter/intranet, video conferencing, optical and speech recognition system. • Hardware devices: ○ computer system, e.g. personal computer, network, plant/process control system ○ input/output devices, e.g. keyboard, scanner, optical/speech recognition device, printer, plotter. • Present information: ○ a report that includes written and technical data, e.g. letters, memos, technical product/service specification, fax/email, tabulated test data, graphical data ○ visual presentation, e.g. overhead transparencies, charts, computer-based presentations (PowerPoint).

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information		
P1 interpret an engineering drawing/circuit/ network diagram		
P2 produce an engineering drawing/circuit/network diagram		
P3 use appropriate standards, symbols and conventions in an engineering sketch/circuit/ network diagram		
Learning outcome 2: Be able to use verbal and written communication skills in engineering settings		
P4 communicate information effectively in written work	M1 assess the effectiveness of a written communication method and identify ways in which it could be improved	D1 justify choice of a specific communication method and the reasons for not using a possible alternative
P5 communicate information effectively using verbal methods.		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Be able to obtain and use engineering information		
P6 use appropriate information sources to solve an engineering task	M2 review the information sources obtained to solve an engineering task and explain why some sources have been used but others rejected	
Learning outcome 4: Be able to use information and communication technology (ICT) to present information in engineering settings		
P7 use appropriate ICT software packages and hardware devices to present information.	M3 assess the effectiveness of an ICT software package and its tools for the preparation and presentation of information.	D2 evaluate the use of an ICT presentation method and identify an alternative approach.

Essential information for tutors and assessors

Resources

Access to information and communication technology resources (including the internet) is essential for the delivery of this unit, as is a well-stocked source of reference material.

Learners should be given a variety of sample written materials (letters, memos, technical reports, data sheets, catalogues) and sketches. Centres will need to give learners access to appropriate presentation and graphics software (for example Microsoft PowerPoint®, Visio), spreadsheet/database software (for example Microsoft Excel®/Access) and computer hardware (for example scanners, printers, optical character recognition and speech recognition software, barcode readers).

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information	Learners will explore a product/circuit/ network and interpret and prepare appropriate engineering sketches/circuit/ network diagrams Learners will produce: • a written report giving their interpretation of the information and features found. • engineering sketches/circuit/ network diagram.
2 Be able to use verbal and written communication skills in engineering settings	Learners will carry out a series of tasks focused on written work and verbal communication methods Learners will complete a portfolio of evidence containing examples of note taking, writing styles, use of diary/logbook and use of graphical presentation techniques. Tutor observation of speaking, listening and use of body language.
3 Be able to obtain and use engineering information	Learners will solve an engineering problem through research and use of information. Learners will complete a written report with suitable reference to the range of sources found and used, including non-computer-based and computer-based resources.

Learning outcome	Recommended assessment approach
4 Be able to use information and communication technology (ICT) to present information in engineering settings	Learners will present engineering information using ICT. Learners will produce a written report on the selection and use of computer hardware devices. Learners will produce a portfolio of evidence of the use of word processing, drawing, data handling and communication software packages to present engineering information.

Learning outcome 1 Be able to interpret and use engineering sketches/circuit/network diagrams to communicate technical information

A single assessment activity could be used to link and capture evidence for the first three pass criteria (P1, P2 and P3). The activity will need to ensure that learners had an opportunity to obtain information, describe features, identify instructions and make use of graphical information (P1). For example, the task could be to work with written operating instructions that include supporting diagrams and sketches (2D and 3D). From the initial investigation, learners could then produce their own drawing and sketches (P2). The criterion P3 would need to be applied to both the interpretation (identify) and the production (use) of their working document.

For Pass standard, learners should interpret (P1) and produce (P2) engineering sketches (2D and 3D)/circuit/network diagrams and sketches. These will need to be at a level sufficient for them to understand and communicate technical information. The use of sketches/circuit/network diagrams in the criteria P1 and P2 is intended to indicate a choice that will depend on the focus of the learning programme in which this unit is being delivered. For example, a learner on a mechanical programme is likely to choose to interpret and produce sketches of components, while a learner studying electrical/electronics is more likely to interpret and produce circuit diagrams. Learners must identify and use of appropriate standards, symbols and conventions (P3).

Learning outcome 2 Be able to use verbal and written communication skills in engineering settings

For Distinction standard, learners should justify their choice of a specific communication method and give detailed and valid reasons for not using a possible alternative (D1). This could be any communication method that the learner has chosen to use (for example drawings, written, verbal).

Learners must consider at least one possible alternative during the initial selection of the method used. Learners will therefore need to be briefed to collect evidence of this selection process, which might otherwise be lost or ignored (for example initial outlines/drafts, notes of any consultation with others on method to be employed). The key issue for this criterion is learners' ability to reflect and evaluate. At pass level, learners will have shown their ability to communicate information effectively and, at merit, to be critical of the content of their own or other people's work. At distinction level, they should be critical of the choice of communication method used.

For Merit standard, learners should assess the effectiveness of their written communication method and identify ways in which it could be improved (M1). The important aspect of this criterion is the learners' ability to use their understanding of communication methods to review their written communication and identify enhancements for example, by using bullet points to condense the content and make it easier to read. It is expected that learners will make the changes that will improve the written communication and highlight the reasons why the changes were made.

For Pass standard, learners should use written communication methods. Their written work must include evidence of note taking, the ability to use a specific writing style, of proofreading and amending text, the use of a diary/logbook and the use of graphical presentation techniques. It might be that not all of these will necessarily occur in a single task/activity. If not, it is acceptable for a number of pieces of assessment evidence to be brought together to meet this criterion. (P4)

The use of verbal methods will require learners to demonstrate speaking and listening skills and an understanding of the impact and use of appropriate body language. The evidence for this should come from one task/activity so that all three aspects are being dealt with at the same time. The activity be a meeting with peers or a supervisor, or could come from a presentation delivered by learners to a group. (P5)

It is important to ensure that learners take questions from the group so that the tutor can capture evidence of learners' ability to listen. The evidence for this criterion is likely to be a tutor observation record or witness statement.

Learning outcome 3 Be able to obtain and use engineering information

For Merit standard, learners will need to review the information sources obtained to solve an engineering task and explain why some sources have been used but others rejected (M2). This criterion is about reflection and the need to carefully consider, measure and express the value (or not) of other people's work as a source of information. Learners need to have identified non-computer-based and computer-based information sources for P6 and it is this material that they should be reviewing for M2. Achievement might well be implicit if the task undertaken for P6 has reached a satisfactory solution, however the expected evidence for this criterion would be a copy of the source material used, suitably annotated to explain its value or why it has been rejected.

For Pass standard, P6 can be assessed using any structured activity that requires learners to identify and use appropriate information sources to solve an engineering task. It is essential that the information comes from both computer-based and non-computer-based sources. The evidence for this criterion could be as simple as suitably referenced work (a bibliography would not be sufficient), however it would be preferable to have a record of the original source and a hard copy, annotated to show the information identified and used for the task (or at least an example of this process).

Learning outcome 4 Be able to use information and communication technology (ICT) to present information in engineering settings

For Distinction standard, learners will evaluate their use of an ICT presentation method and identify an alternative approach. This criterion is about the method of presentation and not the method of communication. It also has a direct link with related Pass (P7) and Merit (M3) criteria. At Pass, learners need to use ICT to present information and, at Merit, to assess the effectiveness of the presentation. For distinction, learners should consider the overall approach taken. For example, could a word-processed technical report have been presented using a computer-based presentation package, such as PowerPoint®, including automated routines and animated graphics or video clips? The evidence for this is likely to be a written evaluation. A rough outline illustrating the identified alternative approach or even a small section of the original reworked using an alternative approach could be used to support the written evaluation. (D2)

For Merit standard, learners assess the effectiveness of an ICT software package and its tools for the preparation and presentation of information. This criterion requires learners to have taken time to reflect on their work and consider the use of software tools available (for example good/consistent use of font size/colour, alignment of text, positioning on the page, use of automated labels, legends and titles for graphs). It is expected that learners will make the changes that will improve the presentation of the information and highlight the reasons why the changes were made. (M3)

For Pass standard, learners could be assessed using any relevant tasks that require them to select and use appropriate ICT software packages and hardware devices to present information. It is essential that the task or tasks chosen for this criterion give learners opportunities to use appropriate software to cover all the ICT applications listed in the content, i.e. there must be evidence of learners' selection and use of ICT for word processing, drawing, data handling and communication (such as email). The requirement for hardware devices is limited to the choice and use of a computer system and relevant input/output devices that would be needed for the task carried out. It is expected that the range of information presented using ICT will include a technical report and visual presentation material, for example overhead transparencies, chart, computer-based presentation (PowerPoint®). (P7)

Unit 3: Mathematics for Engineering Technicians

Level: 3

Unit type: Mandatory

Guided learning hours: 60

Unit introduction

One of the main responsibilities of an engineer is to solve problems quickly and effectively. This unit will enable learners to solve mathematical, scientific and associated engineering problems at technician level. The unit is also a basis for progression to study other units, both in this qualification, for example Unit 15: Further Engineering Mathematics.

This unit enables learners to use their mathematical knowledge in a practical context for their chosen discipline. Learning outcome 1 will develop learners' knowledge and understanding of algebraic methods, from the use of indices in engineering to the use of the algebraic formula for solving quadratic equations. Learning outcome 2 involves the introduction of the radian as another method of angular measurement, the shape of the trigonometric ratios and the use of standard formulae to solve problems involving surface areas and volumes of regular solids. Learning outcome 3 requires learners to represent statistical data in a variety of ways and calculate the mean, median and mode. Finally, learning outcome 4 is intended as a basic introduction to the arithmetic of elementary calculus.

Learning outcomes

In this unit you will:

1 Be able to use algebraic methods

2 Be able to use trigonometric methods and standard formulae to determine areas and volumes

3 Be able to use statistical methods to display data

4 Be able to use elementary calculus techniques.

Content

What needs to be learned
Learning outcome 1: Be able to use algebraic methods
• Indices and logarithms: laws of indices $a^m \times a^n = a^{m+n}$, $\frac{a^m}{a^n} = a^{m-n}$, $(a^m)^n = a^{mn}$; laws of logarithms: $\log A + \log B = \log AB$, $\log A^n = n\log A$, $\log A - \log B = \log \frac{A}{B}$; common logarithms (base 10), natural logarithms (base e), exponential growth and decay. • Equations and graphs: linear equations, e.g. $y = mx + c$; straight-line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line); quadratic graph $y = ax^2 + bx + c$; experimental data, e.g. Ohm's law; pair of simultaneous equations in two unknowns (two linear or one linear and one quadratic). • Factorisation and quadratics: multiply expressions in brackets by a number, symbol or by another expression in a bracket; by extraction of a common factor, e.g. $ax + ay$, $a(x + 2) + b(x + 2)$; by grouping, e.g. $ax - ay + bx - by$; quadratic expressions, e.g. $a^2 + 2ab + b^2$; roots of an equation, e.g. quadratic equations with real roots by factorisation, and by the use of formula.
Learning outcome 2: Be able to use trigonometric methods and standard formulae to determine areas and volumes
• *Circular measure*: radian, conversion of degree measure to radians and vice versa, angular rotations (multiples of π radians), problems involving areas and angles measured in radians, length of arc of a circle $s = r\theta$; area of a sector $A = \frac{1}{2}r^2\theta$ • *Triangular measurement*: functions (sine, cosine and tangent); sine/cosine wave over one complete cycle; graph of tan$A$ as A varies from 0° and 360° confirming $\tan A = \frac{\sin A}{\cos A}$; values of the trigonometric ratios for angles between 0° and 360°; periodic properties of the trigonometric functions; the sine and cosine rule; practical problems, e.g. calculation of the phasor sum of two alternating currents, resolution of forces for a vector diagram. • *Mensuration*: standard formulae to solve surface areas and volumes of regular solids, e.g. volume of a cylinder $V = \pi r^2 h$, total surface area of a cylinder $TSA = 2\pi rh + 2\pi r^2$, volume of sphere $V = \frac{4}{3}\pi r^3$, surface area of a sphere $SA = 4\pi r^2$, volume of a cone $V = \frac{1}{3}\pi r^2 h$, curved surface area of cone $CSA = \pi rl$

What needs to be learned
Learning outcome 3: Be able to use statistical methods to display data
• Data handling: data represented by statistical diagrams, e.g. bar charts, pie charts, frequency distributions, class boundaries and class width, frequency table; variables (discrete and continuous); histogram (continuous and discrete variants); cumulative frequency curves. • Statistical measurement: arithmetic mean, median, mode, discrete and grouped data.
Learning outcome 4: Be able to use elementary calculus techniques
• Differentiation: differential coefficient; gradient of a curve $y = \mathrm{f}(x)$; rate of change; Leibniz notation $\left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)$; differentiation of simple polynomial functions, exponential functions and sinusoidal functions; problems involving evaluation, e.g. gradient at a point. • Integration: integration as reverse of differentiating basic rules for simple polynomial functions, exponential functions and sinusoidal functions; indefinite integrals; constant of integration; definite integrals; limits; evaluation of simple polynomial functions; area under a curve, e.g. $y = x(x - 3)$, $y = x^2 + x + 4$

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Be able to use algebraic methods		
P1 manipulate and simplify three algebraic expressions using the laws of indices and two using the laws of logarithms		
P2 solve a linear equation by plotting a straight-line graph using experimental data and use it to deduce the gradient, intercept and equation of the line	M1 solve a pair of simultaneous linear equations in two unknowns	D1 solve a pair of simultaneous equations, one linear and one quadratic, in two unknowns
P3 factorise by extraction and grouping of a common factor from expressions with two, three and four terms respectively	M2 solve one quadratic equation by factorisation and one by the formula method	

Assessment criteria		
Learning outcome 2: Be able to use trigonometric methods and standard formulae to determine areas and volumes		
P4 solve circular and triangular measurement problems involving the use of radian, sine, cosine and tangent functions		
P5 sketch each of the three trigonometric functions over a complete cycle		
P6 produce answers to two practical engineering problems involving the sine and cosine rule		
P7 use standard formulae to find surface areas and volumes of regular solids for three different examples respectively		
Learning outcome 3: Be able to use statistical methods to display data		
P8 collect data and produce statistical diagrams, histograms and frequency curves		
P9 determine the mean, median and mode for two statistical problems		

Assessment criteria		
Learning outcome 4: Be able to use elementary calculus techniques		
P10 apply the basic rules of calculus arithmetic to solve three different types of function by differentiation and two different types of function by integration.	M3 apply the rules for definite integration to two engineering problems that involve summation.	D2 apply graphical methods to the solution of two engineering problems involving exponential growth and decay, analysing the solutions using calculus.

Essential information for tutors and assessors

Resources

For this unit, learners will need an electronic scientific calculator and access to software packages that support understanding of the mathematical principles and their application to engineering.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable forms of evidence. Centres need to give learners an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Be able to use algebraic methods	Learners will complete a written activity/test that requires them to complete five tasks, one for each criterion.
2 Be able to use trigonometric methods and standard formulae to determine areas and volumes	Learners will complete a written activity that requires them to use trigonometric methods and standard formula to determine areas and volumes.
3 Be able to use statistical methods to display data	Learners will complete a written activity that requires them to collect and display data using different graphical methods, and to evaluate the mean, median and mode for a set of discrete and grouped data.
4 Be able to use elementary calculus techniques	Learners will complete a written activity that requires them to produce calculations, graphical solutions and analysis to demonstrate use of calculus techniques.

Learning outcome 1: Be able to use algebraic methods

For Distinction standard, D1 extends M1 by the introduction of a quadratic equation to be solved simultaneously with a linear equation.

It would be appropriate to use the same assessment method and instrument as P2, possibly combining these two criteria as one assessment activity.

For Merit standard, for M1, learners will need to provide evidence that they can solve a pair of simultaneous linear equations in two unknowns (for example equations formed after the application of Kirchhoff's laws, power transmitted for different belt tensions in a mechanical system).

M2 could be assessed through an assignment, as it requires learners to evaluate the roots of a quadratic equation by factorisation and by the formula method (for example evaluation of an equation formed after the realisation of a practical situation).

For Pass standard, criterion P1 could be assessed in the form of a short written test and could include criterion P3.

For P2 learners should be given a range of data sufficient for them to plot the graph and work out the gradient, intercept and the equation. Data forcing learners to draw the line of best fit, as opposed to a set of points directly on the graphical line, might be appropriate.

Learning outcome 2: Be able to use trigonometric methods and standard formulae to determine areas and volumes

This outcome could be assessed through an assignment or perhaps by combining it with other criteria in a short formal test.

For Pass standard, learners could be given a range of different values and assessed through an assignment or a short formal test. The problems given should cover, collectively, radian, sine, cosine and tangent functions. When considering the content part of this learning outcome, it is important that these problems give learners the opportunity to convert multiples of π radians to degrees and vice versa. The circular measurement problems also need to cover the length of an arc and area of a sector, as well as areas and angles measured in radians. Obviously the triangular measurement problems are more basic and only expect application of the three functions. (P4)

Learners will sketch each of the three trigonometric ratios, this is probably best done as a classroom exercise. (P5)

Learners will produce answers to two practical engineering problems involving the sine and cosine rule (for example calculate the phasor sum of two alternating currents and evaluate the resultant and the angle between two forces). (P6)

Learners will calculate the surface areas and volumes for three different regular solids. (P7)

Learning outcome 3: Be able to use statistical methods to display data

For Pass standard, learners could complete an assignment where they collect meaningful data (for example classification of workers within their company) and display this information using different graphical methods (for example bar charts). They also need to produce a histogram and plot frequency curves (for example resistance values of 100 resistors or external diameter of pins). (P8)

Learners will provide evidence that shows they are able to determine and then explain the relevance of the mean, median and mode for a set of discrete and grouped data (for example time taken to produce components on a machine rounded to the nearest ten seconds and the 100 resistor values or diameters of pins from P8). This could be achieved through an assignment. (P9)

Learning outcome 4: Be able to use elementary calculus techniques

This could be assessed through a written assignment.

For Distinction standard, learners need to apply the graphical methods to the solution of two engineering problems involving exponential growth and decay (for example growth of voltage in a capacitor, radioactive decay, application of Taylor's tool life equation $C = VT^n$) and then analyse the results by applying the appropriate method of differential calculus to check the results. (D2)

For Merit standard, learners demonstrate that they can accurately evaluate two engineering problems involving definite integration (for example area under a velocity-time graph, area under a voltage-current graph). (M3)

For Pass standard, P10 may be assessed through a short, formal test, with learners being given a list of the standard differential coefficients and integrals to use.

Unit 4: Properties and Applications for Engineering Materials

Level: 3

Unit type: Mandatory

Guided learning hours: 60

Unit introduction

In-depth knowledge of the structure and behaviour of engineering materials is vital for anyone expected to select or specify them for applications in the engineering industry. This unit will give learners an understanding of the structures, classifications and properties of materials used in engineering and will enable them to select materials for different applications.

The unit is appropriate for learners engaged in manufacturing and mechanical engineering, particularly where materials are sourced in the form of stock to be used in a production process. The unit covers a range of materials, some of which learners may not be familiar with initially.

This unit will enable learners to identify and describe the structures of metals, polymers, ceramics and composites and classify them according to their properties. Learners will describe the effects of processing on the behaviour of given materials. Smart materials with properties that can be altered in a controlled fashion through external changes – such as temperature and electric and magnetic fields – are also covered.

Learners will apply their understanding of the physical and mechanical properties of materials, design requirements, cost and availability to specify materials for given applications.

All materials have limits beyond which they will fail to meet the demands placed on them. The common modes of failure will be both demonstrated and explained to enable learners to recognise where an informed choice can make the difference between the success or failure of a product.

Note that the use of 'e.g.' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'e.g.' needs to be taught or assessed.

Learning outcomes

In this unit you will:

1 Know the structure and classification of engineering materials

2 Understand material properties and the effects of processing on the structure and behaviour of engineering materials

3 Be able to use information sources to select materials for engineering uses

4 Understand the modes of failure of engineering materials.

Content

What needs to be learned
Learning outcome 1: Know the structure and classification of engineering materials

• Atomic structure: element; atom, e.g. nucleus, electron; compound; molecule; mixture; bonding mechanisms, e.g. covalent, ionic, metallic.
• Structure of metals: lattice structure; grain structure; crystals; crystal growth; alloying e.g. interstitial, substitutional; phase equilibrium diagrams, e.g. eutectic, solid solution, combination; intermetallic compounds.
• Structure of polymeric materials: monomer; polymer; polymer chains, e.g. linear, branched, cross-linked; crystallinity; glass transition temperature.
• Structure of ceramics: amorphous, crystalline, bonded.
• Structure of composites: particulate, fibrous, laminated.
• Structure of smart materials: crystalline, amorphous, metallic.
• Classification of metals:
  ○ ferrous, e.g. plain carbon steel, cast iron (grey, white, malleable, wrought iron), stainless and heat-resisting steels (austenitic, martensitic, ferritic)
  ○ non-ferrous, e.g. aluminium, copper, gold, lead, silver, titanium, zinc; non-ferrous alloys, e.g. aluminium-copper heat treatable – wrought and cast, non-heat-treatable – wrought and cast, copper-zinc (brass), copper-tin (bronze), nickel-titanium alloy.
• Classification of non-metals (synthetic): thermoplastic polymeric materials, e.g. acrylic, polytetrafluoroethylene (PTFE), polythene, polyvinyl chloride (PVC), nylon, polystyrene; thermosetting polymeric materials, e.g. phenol-formaldehyde, melamine-formaldehyde, urea-formaldehyde; elastomers; ceramics e.g. glass, porcelain, cemented carbides; composites, e.g. laminated, fibre reinforced (carbon fibre, glass reinforced plastic (GRP)), concrete, particle reinforced, sintered; smart materials, e.g. electro-rheostatic (ER) fluids, magneto-rheostatic (MR) fluids, piezoelectric crystals.
• Classification of non-metals (natural): e.g. wood, rubber, diamond.

What needs to be learned
Learning outcome 2: Understand material properties and the effects of processing on the structure and behaviour of engineering materials
• Mechanical properties: strength (tensile, shear, compressive), hardness, toughness, ductility, malleability, elasticity, brittleness. • Physical properties: density, melting temperature. • Thermal properties: expansivity, conductivity. • Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity. • Effects of processing metals: recrystallisation temperature; grain structure, e.g. hot working, cold working, grain growth; alloying elements in steel, e.g. manganese, phosphorous, silicon, sulphur, chromium, nickel. • Effects of processing thermoplastic polymers: polymer processing temperature; process parameters, e.g. mould temperature, injection pressure, injection speed, mould clamping force, mould open and closed time. • Effects of processing thermosetting polymers: process parameters, e.g. moulding pressure and time, mould temperature, curing. • Effects of processing ceramics: e.g. water content of clay, sintering pressing force, firing temperature. • Effects of processing composites: fibres, e.g. alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cermets. • Effects of post-production use: smart materials, e.g. impact (piezoelectric), electric field (electro-rheostatic), magnetic field (magneto-rheostatic), temperature (shape memory alloys), colour change (temperature or viscosity).

What needs to be learned
Learning outcome 3: Be able to use information sources to select materials for engineering uses
• Information sources: relevant standard specifications, e.g. British Standards (BS), European Standards (EN), International Standards (ISO); material manufacturers' and stockholders' information, e.g. data sheets, catalogues, websites, DVDs. • Design criteria: properties, e.g. mechanical, physical, thermal, electrical and magnetic; surface finish; durability, e.g. corrosion resistance, solvent resistance, impact resistance, wear resistance. • Cost criteria: initial cost, e.g. raw material, processing, environmental impact, energy requirements; processing, e.g. forming, machining, casting, joining (thermal, adhesive, mechanical); quantity; mode of delivery e.g. bulk, just-in-time (JIT); recycling. • Availability criteria: standard forms, e.g. sheet and plate, bar-stock, pipe and tube, sectional, extrusions, ingots, castings, forgings, pressings, granular, powder, liquid.
Learning outcome 4: Understand the modes of failure of engineering materials
• Principles of ductile and brittle fracture: effects of gradual and impact loading, e.g. tensile, compressive, shear; effects of grain size; transition temperature; appearance of fracture surfaces. • Principles of fatigue: cyclic loading, effects of stress concentrations, e.g. internal, external; effects of surface finish; appearance of fracture surfaces. • Principles of creep: primary, secondary, tertiary, effects of temperature, strain versus time curve, creep limit, effect of grain size, effect of variations in the applied stress. • Tests: destructive, e.g. tensile, hardness, impact, ductility, fatigue, creep; non-destructive, e.g. dye penetrant, ultrasonic, radiographic (x-ray, gamma ray), magnetic powder, visual. • Degradation processes: on metals, e.g. oxidation, erosion, stress corrosion; on polymers, e.g. solvent attack, radiation and ageing; on ceramics, e.g. thermal shock, sustained high temperature.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Know the structure and classification of engineering materials		
P1 describe the structure (including the atomic structure) associated with a given metal, polymer, ceramic, composite and smart material		
P2 classify given engineering materials as either metals or non-metals according to their properties		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 2: Understand material properties and the effects of processing on the structure and behaviour of engineering materials		
P3 explain mechanical, physical, thermal and electrical and magnetic properties and state one practical application of each property in an engineering context	M1 assess how the properties and structure of different given engineering materials affect their behaviour in given engineering applications	
P4 explain the effects on the properties and behaviour of processing metals, polymers, ceramics and composites and of post-production use of smart materials		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Be able to use information sources to select materials for engineering uses		
P5 use information sources to select a different material for two given applications	M2 analyse the criteria considered in the materials selection process	D1 justify selection of an engineering material for one given application
Learning outcome 4: Understand the modes of failure of engineering materials		
P6 explain the principles of the modes of failure known as ductile/brittle fracture, fatigue and creep	M4 assess how one destructive and one non-destructive test procedure produces useful results.	D2 evaluate the results of one test procedure
P7 perform and record the results of one destructive and one non-destructive test method using one metal and one non-metallic material	M3 assess how two given degradation processes affect the behaviour of engineering materials	
P8 explain a different process of degradation associated with each of metals, polymers and ceramics.		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- a selection of exemplar materials and components for viewing, tactile inspection and discussion.
- degraded and failed component specimens.
- access to equipment to conduct at least one destructive and one non-destructive test
- related materials as specified in the unit content.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Know the structure and classification of engineering materials	Leaners will produce a written report relating to the structure and classification of the range of engineering materials.
2 Understand material properties and the effects of processing on the structure and behaviour of engineering materials	Learners will produce a written report relating to the properties and behaviour of engineering materials.
3 Be able to use information sources to select materials for engineering uses	Learners will produce a written report listing selection criteria, information sources and justification for selected materials.
4 Understand the modes of failure of engineering materials	Learners will produce a written report relating to the range of failure modes and degradation processes in engineering materials, and containing an explanation of test procedure and evaluation of test results.

Learning outcome 1: Know the structure and classification of engineering materials and Learning outcome 2: Understand material properties and the effects of processing on the structure and behaviour of engineering materials

For Merit standard, learners will need to assess how the structure and properties of given materials will affect their behaviour in use. For example, how high carbon steel will behave when it is subjected to a load and heat during a machining activity. It is expected that at least five engineering applications will be considered that require five different types of material. This evidence would be best demonstrated by a written task related to the activities carried out to meet P1, P2 and P3. (M1)

For Pass standard, the evidence to satisfy the pass criteria P1, P2 and P3 could be achieved through a written assignment following a combination of tutor-led practical and theory sessions and individual research.

Tutors must provide learners with a range of materials to classify, including at least one ferrous, one non-ferrous, one non-ferrous alloy, one thermoplastic polymer, one thermosetting polymer, an elastomer, one ceramic, one composite, one smart material and one natural material.

Achievement of P4 could involve learners in both practical and theoretical tasks in which they relate the effects of processing on the properties of materials with real engineering applications. For smart materials, they need to consider the effects on the properties of the materials' use after production. Examples here may be related to their change in properties from the effects of external stimuli. For example, when a force is applied to a piezoelectric material, it produces an electric charge that can be used to trigger a car's airbag in the event of an accident. In many applications the behaviour is reversible, for example a colour change in response to a change in temperature or a variation in the viscosity of a liquid in response to the application of an electric or magnetic field.

Learning outcome 3: Be able to use information sources to select materials for engineering uses

For Distinction standard, learners need to justify their selection of one of the materials used to satisfy P5, giving detailed and valid reasons for the selection and why other materials considered for the application were not selected. (D1)

For Merit standard learners will analyse why the properties, stock form, cost, availability, durability, processing method and environmental impact of the materials (from P5) are so important when selecting them. (M2)

For Pass standard learners will use information sources to select different materials for two different applications. The materials selected must be appropriate for the applications. (P5)

Learning outcome 4: Understand the modes of failure of engineering materials

For Distinction standard, learners will to complete a written task to evaluate the results of one of the tests used to meet P7 and M4. (D2)

The evidence would depend on the test used but it could include the mathematical results of a tensile test, the values of a hardness test or detailed information gained from a non-destructive test.

For Merit standard, learners willproduce a written account of the test procedures followed in P7 and analyse the usefulness of the results. In producing evidence for some of this criterion it may be appropriate to include the responses to oral questions. However, centres should ensure that such questions and the responses are recorded for verification and also that they are not the sole source of evidence. It is expected that the learner will consider, for example, ultimate tensile strength and the potential impact of surface cracks. (M3)

M4 could be achieved through an extension of the task given for P8, with a detailed examination of one destructive and one-non-destructive test procedure . The processes used in the learner's analysis could be selected to meet local conditions or industrial applications. It is expected that learner's evidence will detail how the degradation process affected the behaviour of the engineering materials over time.

For Pass standard, P7 could be met using a combination of practical and research activities involving tutor-led demonstrations of available laboratory tests. Learners could then carry out a series of tests and produce a written record of the test results. A witness statement could confirm learner's involvement. Depending on available resources, it may be best to carry out the destructive test on the non-metallic material and the non-destructive test on the metallic material. This would allow a wider choice of tests for the latter.

To achieve P6 and P8, learners will research modes of failure and degradation processes reflected in local conditions, for example a marine environment, or, for employed apprentices, failure and degradation pertinent to their companies' products. They will support their work with examples of and reasons for the different modes of failure and processes of degradation.

Unit 5: Advanced Manual Turning Techniques

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Engineers use a variety of machinery during the manufacture of finished products. By conducting turning operations that rotate about a centre, engineers can produce complex components to close tolerances. However, the machinery can be dangerous to operate.

In this unit learners will learn the theory of advanced manual turning techniques using centre lathes whilst complying with relevant legal requirements and current quality standards. They will explore the concepts of different advanced turning techniques and the types of cutting tools and work holding devices that can be used. They will also learn how to determine the correct machining parameters and how to plan the sequence of operations in order to produce components using advanced turning techniques.

Learning outcomes

In this unit, you will:

1. Understand advanced manual turning techniques
2. Understand how to prepare for advanced manual turning operations
3. Understand the principles of thread cutting using advanced manual turning techniques

Content

What needs to be learned
Learning outcome 1: Understand advanced manual turning techniques

- Procedures, safety precautions and applicable health and safety requirements relating to the mounting of ancillary equipment and accessories on a centre lathe:
    - The specific safety precautions relating to the mounting setting and use of ancillary equipment, work holding devices and accessories on a centre lathe, e.g. faceplates, fixed steadies, travelling steadies, mounting components off centre, taper turning attachment; ensuring that the accessory/ancillary equipment is secure and freedom of movement of cutting tools before starting the machine.
    - Fitting and adjustment of machine guarding.
    - Procedures for checking the emergency mechanisms are working correctly e.g. emergency stop button, guard interlocks.
    - Use of coolant
- Typical advanced turning techniques:
    - taper turning:
        - taper specifications including taper per unit length, tangent, gradient and the included angle
        - methods of producing internal tapers including reamers and taper boring and the advantages / disadvantages and limitations of each method
        - equipment used in taper tuning including compound slide, offset tailstock, form tools, taper turning attachment, fixed stead and travelling steady
        - measurement of internal and external tapers including the use of slips and sine bars and taper plug gauges
    - boring:
        - types of boring equipment and their advantages / disadvantages and limitations in use including standard boring bars, adjustable precision boring units, boring bars made from special materials.
        - limitations of drills when used to produce bores
        - the types and use of reamers to finish bores and their standard geometry
        - the use of data sources to determine the relationship between drilling and reaming

What needs to be learned
- faceplate/eccentric turning: - methods of mounting an eccentric load on a face plate   - calculation of balance weight position on the face plate   - problems associated with out of balance turning e.g. poor surface finish, damaged tooling, damaged machinery, personal injury   - Cutting tools and cutting tool materials: - the purpose of rake and clearance angles as applied to lathe tools   - types of lathe tool including boring bars, parting tools, thread cutting tools (internal and external), turning tools (left and right hand), finishing tools, corner tools   - the purpose of carbide insert chip breakers   - cutting tool material types including HSS, coated HSS, plain and multi-coated tungsten carbides, cermets, CBN/diamond, Polycrystalline Diamond, Polycrystalline Cubic Boron Nitride.   - Benefits and limitations of each cutting tool material type.   - Work holding devices: - typical work holding devices that can be used when thread cutting including, three jaw chuck, four jaw chuck, collet chuck, faceplates   - methods used to protect the surface finish of components during thread cutting operations.

What needs to be learned
Learning outcome 2: Understand how to prepare for advanced manual turning operations

• Planning for advanced manual turning operations:
  ○ determine the machining requirements from component drawings, including:
    – component material type/sizes
    – surface finish
    – dimensions/tolerances
  ○ type of turning operations required, e.g. fixed and traveling steadies, faceplates, balance weights, tailstocks, fixed and revolving centres, types of cutting tool required in relation to the material being cut and tolerance/surface finish requirements.
  ○ sequence of machining operations.
• Types of tooling required e.g. fixed and traveling steadies, faceplates, balance weights, tailstocks, fixed and revolving centres, types of cutting tool required in relation to the material being cut and tolerance/surface finish requirements.
• Machine set-up for given advanced manual turning operations
  ○ parameters that need to be considered when setting a centre lathe for advanced turning operations including:
    – determination of cutting speeds and feed rates by both calculation and the use of charts
    – depth of cut
    – selection of work holding devices/ancillary equipment
    – selection of appropriate cutting tools and setting at centre height
    – setting of stops
    – selection of tools for mounting in the tool post for efficiency
    – adjustment of tool height in relation to centreline of the material.

What needs to be learned
Learning outcome 3: Understand the principles of thread cutting using advanced manual turning techniques
• Thread forms: o geometry of typical metric and imperial single thread forms including UNC, UNF, metric fine, metric coarse, BSW, BSF, square and buttress o typical uses and limitations of thread types o techniques used in multi-pass thread turning using spindle reversal and thread-chasing dials o multi-start threads. • Tooling: o typical tools that can be used to cut screw threads on a centre lathe including taps and dies, internal thread cutting tools, external thread cutting tools o typical materials used to make thread cutting tools including high speed steel, brazed tip, replaceable inserts.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand advanced manual turning techniques		
P1 Explain the health and safety requirements applicable to manual turning operations		
P2 Explain advanced manual turning techniques	M1 Analyse advanced manual turning techniques	D1 Justify the use of advanced manual turning techniques and tooling in a given situation
P3 Explain the types of tooling and equipment available	M2 Compare tooling types and materials and equipment available	
Learning outcome 2: Understand how to prepare for advanced manual turning operations		
P4 Explain the machining set-up chosen to produce a component from a given drawing	M3 Assess the effectiveness of machining set-up chosen to produce the required component to the required tolerances	D2 Justify the machining set-up chosen to produce the required component to the required tolerances

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand the principles of thread cutting using advanced manual turning techniques		
P5 Explain how a typical thread is cut on a centre lathe	M4 Determine the machining parameters required for given thread cutting operations	D3 Interpret the requirements of given internal and external thread cutting operations to prepare detailed work instructions, using consistently correct technical language
P6 Explain the types of tooling used when cutting internal and external threads	M5 Assess the suitability of types of tooling used when cutting internal and external threads	

Essential information for tutors and assessors

Resources

Access to the internet and relevant engineering data tables is needed for this unit. Learners would also benefit from access to engineering workshops with centre lathes, associated cutting tools, work holding devices and ancillary equipment.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment, detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand advanced manual turning techniques	Learners could produce an information leaflet aimed at new apprentices that briefly details the health and safety requirements when conducting advanced manual turning operations. It will also provide details of the types of tooling and associated tooling material types that can be used for taper turning, boring and eccentric turning operations that enables operators to make informed choices regarding the suitability of using different types of techniques/equipment to conduct advanced manual turning operations.
2 Understand how to prepare for advanced manual turning operations	Learners could produce a written report that explains and justifies their selection of tooling, equipment and machining parameters to produce a component to the required tolerances from a given engineering drawing.

Learning outcome	Recommended assessment approach
3 Understand the principles of thread cutting using advanced manual turning techniques	Learners could produce a portfolio of evidence that includes detailed work instructions for a given thread component and an information leaflet aimed at apprentice engineers that details the process of cutting typical internal and external threads on a centre lathe and the types of tooling that can be used.

Learning outcome 1: Understand advanced manual turning techniques

For Distinction standard, learners will go beyond the analysis required for the Merit criteria to compare their preferred machine set-up to provide a clear justification as to why **one** taper turning technique, plus the associated tools, **one** boring technique, plus the associated tools, and **one** eccentric turning technique plus the associated tools are best suited for a given advanced turning operation. Their justification will also detail why alternative techniques can be rejected. For example, drilling and reaming a taper bore may be preferable over other taper boring methods due to the speed of producing the bore and the surface finish requirements (D1).

For Merit standard, learners will go beyond the explanations given for the Pass criteria by detailing the benefits and limitations of the techniques, tools and equipment they have detailed. For example, they could explain why a taper-turning attachment might be used instead of offsetting the tailstock for certain operations. Learners will also compare **four** types of cutting tool material giving their relative benefits and limitations of use (M1, M2).

For Pass standard, learners explain at least **two** techniques that can be used for taper turning operations, at least **two** techniques that can be used for boring operations using suitable component examples. They will also explain how faceplate/eccentric turning operations can be used to turn complex components with valid reasons(P2). They will explain the use of at least **four** tools and **four** pieces of equipment that are available to conduct taper turning, faceplate/eccentric turning and boring operations with valid examples (P3). Learners will also provide a brief explanation setting out the main points of the health and safety requirements pertaining to themselves and their employers in order to conduct turning operations safely (P1).

Learning outcome 2: Understand how to prepare for advanced manual turning operations

For Distinction standard, learners will go beyond the assessment required for the Merit criteria and will justify their selected machining setup, including consideration of alternative approaches that could have been used to manufacture the component from a given engineering drawing. For example, travelling steadies may be preferable over fixed steadies when turning a long shaft due to the diameter of the shaft and shaft runout requirements (D2).

For Merit standard, learners will go beyond the explanations given for the pass criterion to assess the suitability of the chosen machining set up in order to produce the component to the required tolerances. For example, learners could detail why fixed steadies are not the most suitable when turning small diameter shafts (M3).

For Pass standard, learners will explain the machining parameters, such as the material being cut, dimensions, tolerances, surface finish, tooling requirements, speeds and feed rates and the sequence of operations that must be taken into account when planning machining operations for the efficient manufacture of a component from a given engineering drawing (P4).

Learning outcome 3: Understand the principles of thread cutting using advanced manual turning techniques

For Distinction standard, learners will produce detailed work instructions for the manufacture of the threaded component. The work instructions will justify the use of appropriate tooling, techniques and machining parameters and will be sufficiently detailed to enable a third party to setup a centre lathe and manufacture the given component. Learners will use consistently correct technical language (D3).

For Merit standard, learners will go beyond the explanations given for the Pass criteria and will accurately calculate the machining parameters required for two thread cutting operations (one internal, one external) such as cutting speeds, feed rates and depths taking into account surface finish, material specification and cutting tool parameters. Learners are expected to reference and use engineering data tables and manufacturers' specifications where appropriate. (M4) They must also assess the suitability of their selected tooling when cutting an internal and an external thread in order to produce the component to the required tolerances. (M5).

For Pass standard, learners will explain how to use a centre lathe to cut thread types and associated thread geometries featured on a given engineering drawing of a single item component. The component will be sufficiently complex to include at least three different thread types and will include both internal and external threads with one thread form being multi-start. (P5) They will also need to consider the types of tooling used to cut screw threads on a centre lathe to produce the component (P6).

Unit 6: Advanced Manual Milling Techniques

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Engineers use a large variety of machinery during the manufacture of finished products. By conducting milling operations engineers can produce complex parts with close tolerances, however, the machinery can be dangerous to operate.

In this unit you will learn the theory of advanced manual milling techniques that can be used depending upon the type of milling machine in use in the workplace, whilst complying with relevant legal requirements and current quality standards. You will explore the concepts of different advanced milling techniques and the types of cutting tools and work holding devices that can be used. You will also learn how to determine the correct machining parameters and how to plan the sequence of operations in order to produce components using advanced manual milling techniques.

Learning outcomes

In this unit you will:

1 Understand advanced manual milling techniques

2 Understand how to prepare for advanced manual milling operations

3 Understand the principles of cutting gears using advanced manual milling operations

Content

What needs to be learned
Learning outcome 1: Understand advanced milling techniques

• Procedures, safety precautions and applicable health and safety requirements relating to the mounting of ancillary equipment and accessories on a milling machine:
  ○ the specific procedure and safety precautions relating to the mounting, setting and use of ancillary equipment, work holding devices and accessories on a milling machine, e.g. collet chucks, dividing head, tailstock and rotary table; ensuring that the accessory / ancillary equipment is secure and that there is freedom of movement of cutting tools before starting the machine.
  ○ fitting and adjustment of machine guarding.
  ○ procedures for checking the emergency mechanisms are working correctly e.g. emergency stop button, guard interlocks.
  ○ use of coolant.
• Typical advanced milling techniques
  ○ Straddle milling - equipment used in straddle milling including arbour, types of cutters, spacers.
  ○ Spiral milling:
    – equipment used in spiral milling including universal dividing head and tailstock
    – the determination of indexing and angular rotation values using charts and by calculation.
    – types of cutters used in spiral milling.
  ○ Cam milling:
    – equipment used in cam milling including diving head and associated gears, types of cutters used in cam milling
    – determining the correct gear ratio when gearing the dividing head to the lead screw of the table
    – determining the angle of the milling machine spindle from vertical and the dividing head chuck from the horizontal

What needs to be learned
- Dovetail milling: - types of dovetail cutters   - dovetail specifications including male and female parts, dovetail angle, length of dovetail   - measurement of dovetails including parallelism of sides.   - procedure of clamping the material to the mill prior to carrying operations including clamping of female parts on the sides and milling along the y axis, clamping of male parts and milling along the x axis.   - Cutting tools and cutting tool materials   - types of cutting tool materials including High Speed Steel (HSS), ceramics and carbides   - benefits and limitations of each cutting tool material type   - types of cutting tool including slot drills, end mills, dovetail, angle cutters, face mills, slide and face, boring heads, drills and reamers   - the purpose of rake and clearance angles as applied to milling tools and their influence on cutting efficiency   - the benefits and limitations of up-cut milling and climb milling.

What needs to be learned
Learning outcome 2: Understand how to prepare for advanced manual milling operations
• Planning for advanced milling operations - determine the machining requirements from component drawings including component material type/size, surface finish, dimensions/tolerances, type of milling operations required such as straddle milling/spiral milling/cam milling/dovetail milling/gear cutting and sequence of machining operations, types of tooling required such as dividing heads, rotary tables, tailstocks, types of cutters required. • Machine set-up for given advanced manual milling operations - parameters that need to be considered when setting a milling machine for advanced milling operations including determination of cutting speeds and feed rates by both calculation and the use of charts, selection of work holding devices / ancillary equipment, selection of appropriate cutting tools and depth of cut, setting of stops, efficiency of tooling changeover.

What needs to be learned
Learning outcome 3: Understand the principles of cutting gears using advanced manual milling operations
• Gear types: ○ the types of gear in common use including straight spur gears, bevel gears, helical spur gear, spiral bevel gear, mitre gears, worm gears rack and pinions ○ typical uses and limitations of the gear types ○ gear tooth terminology including involute, conformal, base circle, base diameter, pitch circle, pitch diameter, gear tip, tip circle, tip diameter, pressure angle, gear root. • Machining gears using a milling machine: ○ the machine requirements for cutting gears with the correct number of teeth ○ setting and checking of the Pitch Circle Diameter (PCD) of a gear before machining ○ the types of milling cutters that can be used to produce gears including straight toothed spur gears, straight toothed bevel gears, helical spur gears and worm gears ○ types of material used for milling cutters including high-speed steel, cemented carbide tip, stellites, ceramics ○ the principles of gear hobbing its application for the mass production of gears ○ the uses and setting of dividing heads and rotary tables ○ the determination of indexing and angular rotation values using charts and by calculation ○ the procedures for aligning dividing heads and rotary tables including use of parallel setting bars, Dial Test Indicators (DTIs) and approximation.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand advanced manual milling techniques		
P1 Explain the health and safety requirements applicable to milling operations		
P2 Explain advanced manual milling techniques	M1 Analyse advanced manual milling techniques	D1 Justify the use of advanced manual milling techniques and tooling in a given situation
P3 Explain the types of tooling and equipment available	M2 Compare tooling types and materials and equipment available	
Learning outcome 2: Understand how to prepare for advanced milling operations		
P4 Explain the machining set up chosen to produce a component from a given drawing	M3 Assess the effectiveness of machining set-up chosen to produce the required component to the required tolerances	D2 Justify the machining set-up chosen to produce the required component to the required tolerances

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand the principles of cutting gears using advanced manual milling techniques		
P5 Explain how a typical gear is cut on a milling machine	M4 Calculate the machining parameters required for a given gear cutting operation	D3 Interpret the requirements of given gear cutting operations to prepare detailed work instructions, using consistently correct technical language
P7 Describe work holding and indexing and the tooling used when cutting gears	M5 Assess the suitability of work holding and indexing and the tooling used to meet the requirements of a given gear cutting operation	

Essential information for tutors and assessors

Resources

The special resources needed for this unit are: access to the internet and relevant engineering data tables. Learners would also benefit from access to engineering workshops containing milling machines, associated cutting tools, work holding devices and ancillary equipment.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand advanced manual milling techniques	Learners could produce an information leaflet aimed at new apprentices that briefly details the health and safety requirements when conducting advanced manual milling operations. It will also provide details of the types of tooling and associated tooling material types that are available that enables operators to make informed choices regarding the suitability of using different types of techniques/equipment to conduct advanced milling operations including straddle/spiral/cam/dovetail milling.
2 Understand how to prepare for advanced manual milling operations	Learners could produce a written report that explains and justifies the learner's selection of tooling, equipment and machining parameters to produce a component to the required tolerances from a given engineering drawing.

Learning outcome	Recommended assessment approach
3 Understand the principles of cutting gears using advanced manual milling techniques	Learners could produce a portfolio of evidence that includes a detailed work instruction for a given gear cutting operation and an information leaflet aimed at apprentice engineers that details the process of cutting a typical gear on a manual milling machine and the types of work holding and tooling that can be used.

Learning outcome 1 Understand advanced manual milling techniques

For Distinction standard, learners will go beyond the analysis required for the merit criteria to provide a clear justification as to why the chosen advanced milling techniques and tooling are best suited for a given advanced milling operation. The justification will also detail why alternative techniques can be rejected. For example, the justification could include consideration of the material to be machined, dimensional tolerances and efficiency of operation (D1).

For Merit standard, learners will go beyond the explanation given in the pass criteria by analysing the benefits and limitations of the techniques, tools and equipment they have detailed. Learners will also compare **four** types of cutting tool material giving their relative benefits and limitations of use. (M1, M2)

For Pass standard, learners will explain the techniques, tooling and equipment that can be used for **four** advanced milling operations as detailed in the unit content, content (see 1c), using suitable component examples (P2). They will explain the use of at least four tools and four pieces of equipment that are available to conduct the advanced milling operations, with valid examples (P3). Learners will also provide a brief explanation setting out the main points of the health and safety requirements pertaining to themselves and their employers in order to conduct milling operations safely (P1).

Learning outcomes 2 Understand how to prepare for advanced manual milling operations

For Distinction Standard, learners will go beyond the assessment required for the merit criterion and will justify their selected machining setup including a consideration of alternative approaches that could have been used to manufacture the component from a given engineering drawing. For example, they could compare the use of horizontal and vertical milling machines when conducting a range of milling operations, drawing valid conclusions (D2).

For Merit standard, learners will go beyond the explanations given for the pass criteria to assess the suitability of their selected tooling and equipment in order to produce the component to the required tolerances (M3).

For Pass standard, learners will explain the machining parameters, such as the material being cut, dimensions, tolerances, surface finish, tooling requirements, speeds and feed rates and the sequence of operations that must be taken into account when planning machining operations for the efficient manufacture of a component from a given engineering drawing (P4).

Learning outcome 3: Understand the principles of cutting gears using advanced manual milling techniques

For Distinction standard, learners will produce a detailed work instruction for the manufacture of a gear component. The work instruction will justify the use of appropriate work holding devices, tooling, techniques and machining parameters and will be sufficiently detailed to enable a third party to setup a milling machine and manufacture the given component. Learners will consistently use correct technical language (D3).

For Merit standard, learners will go beyond the explanations given for the pass criteria and will accurately calculate the appropriate machine parameters for the gear cutting operation such as cutting speeds, indexing and depths, taking into account surface finish, material specification and cutting tool parameters. Learners would be expected to reference and use engineering data tables and manufacturers' specifications where appropriate. (M4). They must also assess the suitability of their selected work holding and indexing equipment, and the tooling used, when cutting a gear in order to produce the component to the required gear specification (M5).

For Pass standard, learners will explain how to use a milling machine to cut a typical gear featured on a given engineering drawing of a single item component. (P5) They will also need to explain the use of work holding devices and tooling and how indexing is used to produce a gear on a milling machine (P6).

Unit 7: Advanced Manual Milling and Turning Techniques

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Engineers use a large variety of machinery during the manufacture of finished products. By conducting advanced milling and turning operations engineers can produce complex parts with close tolerances, however, the machinery can be dangerous to operate.

In this unit you will learn the theory of how to undertake advanced manual milling and turning operations using milling machines and centre lathes whilst complying with relevant legal requirements and current quality standards. You will explore the concepts of different advanced milling and turning techniques and the types of cutting tools and work holding devices that can be used.

Learning outcomes

In this unit you will:

1 Understand health and safety relating to advanced manual milling and turning techniques.

2 Understand advanced manual milling and turning techniques.

3 Understand how to prepare for advanced manual milling and turning operations.

Content

What needs to be learned
Learning outcome 1: Understand health and safety relating to advanced manual milling and turning techniques
• Procedures, safety precautions and applicable health and safety requirements relating to the mounting of ancillary equipment and accessories on a milling machine: ○ the specific procedures, safety precautions and appropriate health and safety requirements relating to the mounting, setting and use of ancillary equipment, work holding devices and accessories on a milling machine, e.g. collet chucks, dividing head, tailstock and rotary table; ensuring that the accessory/ancillary equipment is secure and that there is freedom of movement of cutting tools before starting the machine. ○ fitting and adjustment of machine guarding ○ procedures for checking the emergency mechanisms are working correctly e.g. emergency stop button, guard interlocks ○ use of coolant ○ environmental considerations such as safe/correct disposal of waste e.g. swarf, coolant, offcuts of material and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults ○ relevant environmental management legislation and regulations e.g. EU waste legislation, hazardous waste regulations.
Learning outcome 2: Understand advanced manual milling and turning techniques
• Typical advanced milling techniques: ○ Straddle milling - equipment used in straddle milling including arbour, types of cutters, spacers. ○ Spiral milling: – equipment used in spiral milling including universal dividing head and tailstock – the determination of indexing and angular rotation values using charts and by calculation. – types of cutters used in spiral milling. ○ Cam milling: – equipment used in cam milling including diving head and associated gears, types of cutters used in cam milling

What needs to be learned
– determining the correct gear ratio when gearing the dividing head to the lead screw of the table – determining the angle of the milling machine spindle from vertical and the dividing head chuck from the horizontal. o Dovetail milling: – Types of dovetail cutters – Dovetail specifications including male and female parts, dovetail angle, length of dovetail – Measurement of dovetails including parallelism of sides – Procedure of clamping the material to the mill prior to carrying operations including clamping of female parts on the sides and milling along the y axis, clamping of male parts and milling along the x axis. • Cutting tools and cutting tool materials used for milling: o types of cutting tool materials including high speed steel (hss), ceramics and carbides o benefits and limitations of each cutting tool material type o types of cutting tool including slot drills, end mills, dovetail, angle cutters, face mills, slide and face, boring heads, drills and reamers o the purpose of rake and clearance angles as applied to milling tools and their influence on cutting efficiency o the benefits and limitations of up-cut milling and climb milling. • Typical advanced turning techniques: o taper turning: – taper specifications including taper per unit length, tangent, gradient and the included angle – methods of producing internal tapers including reamers and taper boring and the advantages / disadvantages and limitations of each method – equipment used in taper tuning including compound slide, offset tailstock, form tools, taper turning attachment, fixed and travelling steadies – measurement of internal and external tapers including the use of slips and sine bars and taper plug gauges.

What needs to be learned
- boring: - types of boring equipment and their advantages/disadvantages and limitations in use including standard boring bars, adjustable precision boring units, boring bars made from special materials.   - limitations of drills when used to produce bores.   - the types and use of reamers to finish bores and their standard geometry.   - the use of data sources to determine the relationship between drilling and reaming.   - faceplate/eccentric turning: - methods of mounting an eccentric load on a face plate.   - calculation of balance weight position on the face plate   - problems associated with out of balance turning e.g. poor surface finish, damaged tooling, damaged machinery, personal injury.
- Cutting tools and cutting tool materials used for turning: - The purpose of rake and clearance angles as applied to lathe tools.   - Types of lathe tool including boring bars, parting tools, turning tools (left and right hand), finishing tools, corner tools   - The purpose of carbide insert chip breakers.   - Cutting tool material types including HSS, Coated HSS, plain and multi-coated tungsten carbides, cermets, CBN/Diamond, Polycrystalline Diamond, Polycrystalline Cubic Boron Nitride.   - Benefits and limitations of each cutting tool material type.

What needs to be learned
Learning outcome 3: Understand how to prepare for advanced manual milling and turning operations
• Planning for advanced manual milling operations: o Determine the machining requirements from component drawings including component material type/size, surface finish, dimensions/tolerances, type of milling operations required such as straddle milling/spiral milling/cam milling/dovetail milling and sequence of machining operations o types of tooling required such as dividing heads, rotary tables, tailstocks, types of cutters required, types of cutting tool required in relation to the material being cut and tolerance/surface finish requirements. • Machine set-up for given advanced manual milling operations: o Parameters that need to be considered when setting a milling machine for advanced milling operations including determination of cutting speeds and feed rates by both calculation and the use of charts, selection of work holding devices /ancillary equipment, selection of appropriate cutting tools and depth of cut, setting of stops, efficiency of tooling changeover. • Planning for advanced manual turning operations: o Determine the machining requirements from component drawings including component material type/sizes, surface finish, dimensions/tolerances, type of turning operations required such as boring /taper turning/faceplate turning, and sequence of machining operations. o Types of tooling required such as fixed and traveling steadies, faceplates, balance weights, tailstocks, fixed and revolving centres, types of cutting tool required in relation to the material being cut and tolerance/surface finish requirements. • Machine set-up for given advanced manual turning operations: o Parameters that need to be considered when setting a centre lathe for advanced turning operations including determination of cutting speeds and feed rates by both calculation and the use of charts, depth of cut, selection of work holding devices / ancillary equipment, selection of appropriate cutting tools and setting at centre height, setting of stops, selection of tools for mounting in the tool post for efficiency, adjustment of tool height in relation to centreline of the material.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: : Understand health and safety relating to advanced manual milling and turning techniques		
P1 Explain the procedures and safety precautions and health and safety requirements applicable to the mounting of equipment and accessories to milling machines and centre lathes	M1 Assess the key features of the health and safety requirements applicable to advanced milling operations and advanced turning operations	
Learning outcome 2: Understand advanced manual milling and turning techniques		
P2 Explain advanced manual milling and turning techniques	M2 Analyse advanced manual milling and turning techniques	D1 Justify the use of advanced manual milling and turning techniques and tooling in a given situation
P3 Explain the types of milling and turning tooling and equipment required	M3 Compare milling and turning tooling types and materials and equipment required	

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand how to prepare for advanced manual milling and turning operations		
P4 Explain the machining set-up to produce a milled component from a given drawing	M5 Assess the effectiveness of machining set-ups chosen to produce the required milled and turned components to the required tolerances	D3 Justify the machining set-ups chosen to other possible set-ups that could be used to produce the required milled and turned components to the required tolerances
P5 Explain the machining set-up to produce a turned component from given drawing		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are access to the internet and relevant engineering data tables. Learners would also benefit from access to engineering workshops containing centre lathes, milling machines, associated cutting tools, work holding devices and ancillary equipment.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand health and safety relating to advanced milling and turning techniques	Learners could produce an information leaflet aimed at new apprentices that explains the key features of health and safety requirements relating to advanced manual milling and turning operations. It will also explain the specific procedures and safety precautions applied when conducting tasks involving advanced manual milling and turning.
2 Understand advanced manual milling and turning techniques	Learners could produce a written report that explains and justifies the techniques, types of tooling and equipment that is available and required to conduct advanced milling and turning operations including the types of materials that tooling can be manufactured from.

Learning outcome	Recommended assessment approach
3 Understand how to prepare for advanced milling and turning operations	Learners produce a written report that explains the parameters that must be considered when planning the machining operations for one given milled component and one given turned component. They will also consider the effectiveness of the set-ups and what other set-ups could be used for both components.

Learning outcome 1 Understand health and safety relating to advanced manual milling and turning techniques

For Merit standard, learners will go beyond the explanation given in the pass criteria by assessing the key features of health and safety requirements that are relevant to the safe operation of milling machines and centre lathes during advanced machining operations. Learners will appraise relevant machining situations that the requirements apply to and consider what may happen if the said requirements were not applied (M1).

For Pass standard, learners will explain the procedures and specific safety precautions that must be applied when mounting equipment and accessories to manual milling machines and centre lathes so they can conduct milling and turning operations. Learners will support their work with at least **four** valid examples - **two** for milling and **two** for turning (P1).

Learning outcome 2 Understand advanced manual milling and turning techniques

For Distinction standard, learners justify the types of tooling and equipment that can be used for one given advanced manual turning operation and one given advanced manual milling operation and give details why the chosen tools and equipment are better suited to the operation than other types available. Their justification will detail why alternative techniques, tooling and equipment can be rejected for the advanced manual turning operation and the advanced manual milling operation. For example, they will explain why a certain work holding device would be used over another type. (D1).

For Merit standard, learners will go beyond the explanations for the pass criteria to provide a detailed analysis of how the operations are conducted. For example, how a centre lathe is set up to conduct turning of a long shaft using fixed and travelling steadies (M2). They will also compare the type of milling and turning tools and equipment that are required for use giving the advantages and disadvantages of each type in context. Learners will also compare four types of cutting tool material giving their relative benefits and limitations of use (M3).

For Pass standard, learners will explain **one** type of advanced manual milling operation and **one** advanced manual turning operation. For example, they could explain how a centre lathe is used to conduct taper boring operations and how a milling machine is used to produce accurate dovetail slots with relevant examples (P2). Learners will also need to explain the types of tooling and the types of work holding devices and other equipment required to conduct the milling and turning operations with valid reasons (P3).

Learning outcome 3 Understand how to prepare for advanced milling and turning operations

For Distinction standard, learners will justify the machining set-ups chosen to produce the required milled and turned components to the required tolerances. Their justification should include a consideration of other possible set-ups that could be used. The other possible set-ups will be detailed in full and learners will provide valid reasons why the original set-ups chosen are more valid, when considering machining efficiency, tolerances, surface finish, safety and costs (D3).

For Merit standard, learners will go beyond the explanations given in the pass criteria and will assess the effectiveness of the machining set-ups chosen to produce the milled component and the turned component. They will show their consideration of appropriate machining parameters for the milling and turning operations, such as cutting speeds and feed rates, taking into account surface finish, material specification and cutting tool parameters. They will include details of why their selected tooling, equipment and work holding devices are suitable in order to produce the components to the required tolerances. Learners are expected to show in their assessment evidence that they have used engineering data tables, manufacturers specifications and where appropriate, carried out calculations to determine the appropriate machine set-up parameters (M5).

For Pass standard, learners will use the given engineering drawings of two components, one milled and one turned, to explain how to set-up a centre lathe and milling machine to produce them both. The learners will need to consider the use of tooling, equipment and work holding devices and explain how the component could be mounted securely without damaging finished surfaces in order to produce the components. There is no expectation that the learners will produce the components, but they will provide details of the steps to be undertaken in planning for the machining operations (P4, P5).

Unit 8: CNC Programming

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

Unit introduction

Computer Numerically Controlled (CNC) programming is used as a method of controlling machining tools using computers and digital circuitry. The ability to successfully complete numerical programming facilitates the automation of the production of parts, meaning that products and items can be produced quickly and economically.

The purpose of this unit is to introduce manual programming for CNC applications. You will gain an understanding of the basic concepts of typical CNC program structures. You will learn how to program repetitive CNC operations using subroutines, loops and 'canned' cycles. You will know how to write a CNC program to cut a part. Finally, you will determine how to debug your program and set-up and use the program safely to operate a CNC machine.

Learning outcomes

In this unit you will:

1 Understand the principles of numerical control programming language

2 Know how to write and use numerical control programs to produce a part

3 Know how to program repetitive numerical control machine operations

4 Understand how to safely communicate with and set up a numerical control machine

Content

What needs to be learned
Learning outcome 1: Understand the principles of numerical control programming language

• Moving in three-dimensional (3D) space:
  ○ axis e.g. z-axis, x-axis, y-axis, coordinates; directions e.g. positive cutting tool and the direction for different spindles; location e.g. origin, datum points; positioning e.g. absolute and incremental positioning of the cutting tool.
• Program structure:
  ○ program structure: blocks e.g. End of Block (EOB), flow charts to represent program blocks; statements; 'canned cycle'; characters; register e.g. Tool Length Offset
  ○ program formats and syntax e.g. fixed sequential, tab sequential and word address.

Learning outcome 2: Know how to write and use numerical control programs to produce a part

• Key steps for programming cutting tools
  ○ data to control the destination of the cutter, the cutting path e.g. point-to-point or continuous
  ○ speed of travel e.g. rapid or federated; action of the cutter at the destination e.g. move to the next destination, drill or stop cutting.
• Features and benefits of different types of commands:
  ○ modal, non-modal and axis commands
  ○ cutting commands for tool motion including linear, radius or circular (arc) motion
  ○ miscellaneous commands including those to facilitate automatic or manual tool changing, control and selection of the spindle speed, control of the feed rate.
• Preparatory code and function:
  ○ types e.g. G-Code, M-Code, S-Code, T-Code
  ○ code address categorisation e.g. move the cutter, offset the centre of the cutter, accept measurement data, position, relocate the origin, execute 'canned' cycles, modify operational characteristics.

What needs to be learned
Learning outcome 3: Know how to program repetitive numerical control machine operations
• Sub Routines or macro: o difference between sub-routines and sub-programs o types and use of sub-routines in code e.g. milling of repetitive groove, pockets or holes o sub-routine programming rules e.g. identifying the sub-routine o specifying sub-routine content, means to call up the sub-routine for execution o sub-routine syntax e.g. branching commands, sub-routine labels, end of sub-routine demarcation, nesting. • Loops: o purpose of loops o typical use of loops e.g. drilling a linear array of holes; loop programming rules e.g. identifying the end or beginning of the loop, specifying where to loop back to or from, declaring the number of times the loop repeat; do-loop syntax. • 'Canned 'or Fixed Cycles: o purpose of 'canned' cycles o types of 'canned' cycles e.g. fixed, roughing, threading, drilling, tapping; programming a machining activity using 'canned' cycles; customised 'canned' cycles; advantages of the adoption of 'canned' cycles.
Learning outcome 4: Understand how to safely communicate with and set up a numerical control machine
• Program debugging: o simulations and 'dry-runs' of programs o locating and removing bugs, errors and abnormalities o debugging tools o benefits of debugging e.g. improvement in cycle time or lengthened too life. • CNC machine set up: o Loading the program onto the machine interface, clamping the part, setting tools, locating the origin point, running the program.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand the principles of numerical control programming language		
P1 Describe the three-dimensional space parameters controlled in a CNC program		
P2 Describe with the aid of a program flow chart the structure of a given CNC program	M1 Assess the importance of different parts of a given CNC program	
Learning outcome 2: Know how to write and use numerical control programmes to produce a part		
P3 Describe the key steps that must be programmed in to control a CNC cutting tool	M2 Compare the features and benefits of different types of CNC program command	D1 Evaluate the features and benefits of different types of command within a given structure of a CNC program used to cut a given part
P4 Describe different types of CNC program command		
P5 Explain the typical address categorisation used in CNC program code		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Know how to program repetitive numerical control machine operations		
P6 Describe the purpose and features of sub-routines and sub programs used in a given CNC program	M3 Compare the use of sub-routines, sub-programs, loops and 'canned' cycles used in two given CNC programs	
P7 Describe the purpose and features of loops used in a given CNC program		
P8 Describe the purpose and features of 'canned' cycles used in a given CNC program		
Learning outcome 4: Understand how to safely communicate with and set up a numerical control machine		
P9 Describe the process of debugging a CNC program	M4 Assess the importance of debugging a CNC program to ensure the safe cutting of a given part using a CNC machine'	D2 Evaluate the benefits and importance of debugging a CNC program to achieve the safe and efficient set-up of a CNC machine to cut a given part
P10 Describe the safe set-up of a CNC machine using a CNC program		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- access to a two- or three- axis CNC machine tool
- access to a two- or three- axis machine tool which can be programmed with data from a computer system
- access to a computer with a CNC program language platform
- examples of CNC program code for different machining applications.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

It is not expected that learners should be able to program and set-up CNC machines to an expert level, but rather be able to describe or interpret elements of the code and this should be taken into account when designing assessments. It is anticipated that learner evidence can be generic and not specific to any particular type of CNC machine.

Learning outcome	Recommended assessment approach
1 Understand the principles of numerical control programming language	A portfolio requiring learners to demonstrate their knowledge of the underlying principles of CNC programming language. Learners complete tasks in which they need to produce a written description of the CNC three-dimensional space parameter, and a program flow chart describing the key structural elements of a CNC program, with a consideration of the importance of each aspect.

Learning outcome	Recommended assessment approach
2 Know how to write and use numerical control programmes to produce a part	A portfolio relating to a CNC program code used to cut a given part. Learners interpret a given CNC code, to write a part program. Learners describe the sequence of key program instruction within the given code using a flow chart format. Learners explain in a written guide the address categorisation code used in CNC programs. Additionally, learners will consider the features and benefits of different types of CNC program command within the code.
3 Know how to program repetitive numerical control machine operations	An assignment requiring learners to demonstrate their knowledge of how to program repetitive numerical control machine operations. Learners complete written tasks for which they need to produce a description/comparison of the purpose and features of sub-routines and sub programs, loops and 'canned' cycles.
4 Understand how to safely communicate with and set up a numerical control machine	Learners will prepare a written portfolio illustrated with photographs and diagrams to describe the steps required to safely set-up the CNC machine using a program code. Learners will also consider the process of debugging a CNC program to cut a given part and will examine the importance of this to ensure safe and efficient set-up of the CNC machine.

Learning outcome 1: Understand the principles of numerical control programming language

For Merit standard, learners will assess the importance of all the parts of a given CNC program code including details of the contribution of each, arriving at a valid conclusion on their importance. The evidence should consider key syntax statements such as the End of Block, as well as the principle elements of code structure. (M1)

For Pass standard, learners will need to evidence sufficient knowledge of how to position a generic CNC cutter in relation to an origin point in three axes. To achieve this learners will give a clear account of the x-axis, y-axis and z-axis, directions, location, and absolute positioning of a tool. (P1)

Learners will also produce a program flow chart interpreting the structure of a given CNC program. Learners should annotate the program flow chart with comments covering details of the program formats. Learners should demonstrate a clear understanding of the principle structure elements of the code. A detailed understanding of every line of code syntax is not anticipated. (P2)

Learning outcome 2: Know how to write and use numerical control programs to produce a part

For Distinction standard, learners evaluate the features and benefits of different types of command within a given structure of a CNC program used to cut a given part. Learners will bring together all the information about the features and benefits of different types of command. Learners will draw on their evidence including relevant data relating to each command to form a conclusion about the contribution of each Factors considered might be how robust certain commands are against the likelihood of error and how easy they are to program. (D1)

For Merit standard learners compare the features and benefits of different types of command used in CNC programs. Learners will be expected to give clear details of the difference and similarities between the tasks performed by each command within a program used to cut a part. (M2)

For Pass standard, learners describe the sequence of key program instruction in a flow chart format. This description includes key commands such as the destination of the cutter, cutting path, speed of travel and action of cutter at the destination. (P3)

Learners give a clear description of different program commands within the code, including modal, non-modal and axis commands, cutting commands for tool motion, for example linear, radian or circular and miscellaneous commands, for example to facilitate tool changing, select spindle speed or control feed rate. (P4)

Learners explain using a written guide the address categorisation used in the CNC program code, for example, S-Code influencing spindle speed or T-Code for tool selection. (P5)

Learning outcome 3: Know how to program repetitive numerical control machine operations

For Merit standard, learners compare the use of sub-routines, sub-programs, loops and 'canned' cycles used in two given CNC programs. Learners will be expected to show they clearly understand the differences and similarities between the tasks performed within each of the programs and will provide a suitable conclusion as to which program is most efficient and why. (M3).

For Pass standard learners will describe the purpose and features of sub-routines and sub programs (P6), loops (P7) and 'canned' cycles (P8) used in a given CNC program. Learners will give details of the specific task/s that each perform in a program and how to recognise each of them by specific start and end syntax within the body of the program.

Learning outcome 4: Understand how to safely communicate with and set up a numerical control machine

F**or Distinction standard**, learners will draw together all their information to evaluate the benefits and importance of debugging a CNC program to achieve the safe and efficient set-up of a CNC machine to cut a given part. Learners will consider, for example, the benefits upon the minimisation of cycle time, the length of tool life, the safety of the operator and the importance in relation to planned maintenance and possible downtime, and will reach valid and detailed conclusions. (D2)

For Merit standard, learners assess the importance of debugging a CNC program to ensure the safe set-up and cutting of a CNC machine to cut a given part. The learner's response will be contextualised and will, for example, consider all aspects of program debugging, and the verification of a program before its actual use on the machine, drawing valid conclusions on its importance, for example, improved cycle time or lengthened tool life. (M4)

For Pass standard, learners describe the processes involved in debugging a CNC program. Learners will give examples of typical errors and describe the purpose and use of debugging tools and simulations to diagnose potential problems. (P9) Learners will describe the safe set-up of a CNC machine using a CNC program including clamping the part, setting tools, locating the origin point and running the program. (P10)

Unit 9 Advanced CNC Turning Techniques

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

The demand for high quality machined components with low lead times has led to the automation of traditional engineering machinery such as centre lathes and milling machines. These Computer Numerical Control (CNC) machines are complex to operate and require the machine operator to have skills that are different to those required for manual machining. For example, they may need to be able to generate a part program and will spend more time on set-up and testing.

In this unit you will learn how to safely operate these machines whilst complying with relevant legal requirements. You will explore how CNC lathes undertake advanced turning operations, the types of cutting tools and work holding devices that can be used and how to produce computer programs for the manufacture of components. This unit is a theoretical unit and learners are not expected to manufacture actual components.

Learning outcomes

In this unit you will:

1 Understand the principles of computer numerical control (CNC) turning operations

2 Understand how to interpret a component specification and produce an operational plan for its manufacture

3 Understand how to produce and test part programs for the manufacture of a turned component using manual programming and CAD/CAM procedures

Content

What needs to be learned
Learning outcome 1: Understand the principles of computer numerical control (CNC) turning operations
• Health and safety requirements associated with CNC turning operations: o duties of employers and employees under relevant legislation and regulations including HASAWA, PUWER, Control of Noise at Work Regulations, PPE Regulations, Manual Handling Regulations, Display Screen Equipment Regulations. • Hazards associated with CNC operations and their control: o the hazards associated with CNC turning operations including high speed operation, manual handling of work pieces and equipment, automatic operation of tool and work handling devices, lack of operator control or intervention, noise levels o the control of hazards associated with CNC operations including operator training, emergency shutdown procedures, enclosed and interlocked guards, use of PPE. • Main features of CNC turning systems: o the function of the main parts of a CNC system including the machine control unit, drive mechanisms, tool/workpiece interface, transducers, feedback, correction, Central Processing Unit (CPU), drive motors, quick change tooling, turret tools, cooling systems, display screens o CNC machining parameters including datum points, designation of axes, definition of parameters using numerical coding, for example position, movement, spindle speeds, cutting tools, clamping.
Learning outcome 2: Understand how to interpret a component specification and produce an operational plan for its manufacture
• Component specification: o interpretation of a detailed drawing to obtain set-up data including material type, reference points including edge datum and centre line datum, dimensions including external, internal, bore diameters, bore depths, tolerances and surface finish. • Operational Plan: o zero datums o work holding equipment such as chucks, faceplates, setting points o sequence of operations including loading, machining, roughing, finishing, measurement, unloading

What needs to be learned
- calculation of tool path coordinates, tool compensation, cutting speeds, feed rates   - grouping of similar operations   - CNC lathe tooling including external turning tools, parting tools, boring bars, drills, reamers, interior and exterior thread cutting tools   - special requirements relating to specific materials   - inspection and proving against specification.
Learning outcome 3: Understand how to produce and test part programs for the manufacture of a turned component using manual programming and CAD/CAM procedures
- Features of manual part programming software: - navigation around the user interface including menu bar, identification line, tool display window   - system status including work/tool relationships including position, direction, amount of movement   - rates of change of parameters including feed rates and spindle speeds   - auxiliary functions including metric and imperial units, tool selection, cutting fluids   - relevant CNC program codes and their functions, for example G codes, M codes, T codes   - dimensional information including axis co-ordinates, absolute, incremental   - block format, for example block number, program code, coordinates   - special function program codes, for example measuring system, tool compensation, canned cycles   - subroutines including tool change, work holding, spindle speed, spindle direction.   - Features of a CAD/CAM package: - typical hardware configuration including CAD workstation, data storage, hard copy equipment, network system   - typical software packages for example, Solidworks, Catia, Autodesk Inventor, Denford VR milling/turning   - typical data formats including extensions and proprietary formats, for example DXF, IGS, DWG, CDR, PCX, PLT.

What needs to be learned
• Part program production and testing: o 3D geometric model using CAD software o selection of machining operations o selection of tooling o generation of CNC program using CAM software o simulation of tool changing and tool paths o program correction and editing o transfer of data files to CNC machine o pre-manufacture run through using graphics display on CNC machine, prove program, dry run.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand the principles of computer numerical control (CNC) turning operations		
P1 Explain how a CNC lathe differs from a manual centre lathe	M1 Compare the use of CNC lathe and a manual centre lathe in relation to the manufacture a given component	D1 Justify the use of CNC lathe over a manual centre lathe in relation to the manufacture of a given component.
Learning outcome 2: Understand how to interpret a component specification and produce an operational plan for its manufacture		
P2 Describe the CNC turning set-up and the cutting tools needed to produce a component from given detail drawing	M2 Interpret the requirements from the given detail drawing to form a CNC turning operational plan for a given component	D2 Justify the order in which CNC turning operations are planned for a given component

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand how to produce and test part programs for the manufacture of a turned component using manual programming and CAD/CAM procedures		
P3 Produce and test a part program using manual CNC part programming for a given component drawing	M3 Assess the part program using a simulation to ensure it effectively meets the requirements of the given component drawing	D3 Justify amendments to the manual part program in order to optimise the cycle time
P4 Use a CAD/CAM package to produce a part program from a given component drawing	M4 Evaluate the benefits of using CAD/CAM software over manual CNC part programming.	

Essential information for tutors and assessors

Resources

The special resources needed for this unit are: access to the internet and relevant engineering data tables. Learners would also benefit from access to engineering workshops containing CNC lathes, associated cutting tools, work holding devices and ancillary equipment. They will also need access to CNC part programming and CAD/CAM software.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand the principles of computer numerical control (CNC) turning operations	A written report for which learners will need to produce a justification of the use of a CNC lathe over a manual centre lathe to produce a given component. As part of this, they will detail how a CNC lathe differs from a manual centre lathe in terms of the main features of the machines, their safe operation and the different forms of control.
2 Understand how to interpret a component specification and produce an operational plan for its manufacture	A practical task in which learners are provided with a detailed drawing and information about a component which they need to interpret. Learners will produce an operational plan to manufacture the product on a CNC lathe and justify the sequence of operations detailed in their operational plan.

Learning outcome	Recommended assessment approach
3 Understand how to produce and test part programs for the manufacture of a turned component using manual programming and CAD/CAM procedures	A practical task in which learners must use the operational plan developed in learning outcome 2 to manually produce and prove a part program for the manufacture of the given component. In a further written task, learners will justify any amendments made to the program in order to meet the requirements of the component specification. Learners will then use a CAD/CAM package to produce the part programme for the same component before evaluating the benefits of using CAD/CAM software over CNC manual part-programming.

Learning outcome 1 Understand the principles of computer numerical control (CNC) turning operations

For Distinction standard, learners will go beyond the comparison given for the merit standard and justify the use of a CNC lathe over a manual centre lathe to produce the given component, with detailed reasons. Learners should, where possible, support their justification using examples from their own workplace (D1).

For Merit standard, learners will go beyond the explanation given in the pass standard and will compare the benefits / limitations of using a CNC lathe over a manual centre lathe in order to manufacture a component from a given detailed drawing. They must also include details of the how the manufacture of the component will differ using each (M1). The given component must be sufficiently complex for manufacture using a CNC lathe to be a sensible consideration.

For Pass standard, learners will explain how a CNC lathe differs from a manual centre lathe in terms of the main features of the machines, their safe operation and the different forms of control. As part of this, learners will also provide a brief explanation setting out the main points of the health and safety legislation and regulations pertaining to themselves and their employers in order to conduct CNC turning operations safely (P1).

Learning outcome 2 Understand how to interpret a component specification and produce an operational plan for its manufacture

For Distinction standard, learners will go beyond the production of an operational plan by providing details of the decisions they took when generating the said plan, with detailed reasons to support these decisions. As a minimum, the justification will relate to the sequencing of the machining operations (D2).

For Merit standard, learners will go beyond the description in the pass standard and will produce a comprehensive operational plan for the manufacture of the given component shown in the detailed engineering drawing. Learners will need to support their operational plan using additional evidence in the form of annotated drawings detailing proposed tooling paths as appropriate, annotated specification sheets and calculations to support machining decisions such as speeds and feed rates (M2).

For Pass standard, learners will give a clear account of how a CNC lathe is to be set-up in order to produce a component using CNC turning techniques from a given detailed engineering drawing (component specification). They will also describe all of the types of cutting tools required to produce the component. (P2).

Learning outcome 3 Understand how to produce and test part programs for the manufacture of a turned component using manual programming and CAD/CAM procedures

For Distinction standard, learners will produce a written report that justifies any amendments they have made to their original manual part program, with detailed reasons to support the changes. For example, they may have amended it in order to reduce the run time and condense the number of steps and tool changes required (D3).

For Merit standard, learners will go beyond the requirements for the pass standard and will produce a written report that reviews their manually produced part program and assesses where improvements to it could be made before reaching a conclusion on how well it enables the component to be manufactured to the specification detailed in the given component drawing (M3). Learners will also evaluate the benefits and limitations of using CAD/CAM software to produce CNC programs over the use of manual CNC part programming. They will need to draw valid conclusions to their arguments that are appropriately supported with detailed reasons and examples (M4).

For Pass standard, learners will produce and test a manual CNC part program from the operational plan developed during the assessment for Learning Outcome 2. They will generate annotations on their part program that explain the sequence of machining operations (P3)

Learners will also produce a part program for the same component using CAD/CAM software (P4). Their evidence will include a range of annotated screenshots for both the manual programming and the programming using CAD/CAM software.

Unit 10 Advanced CNC Milling Techniques

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

The demand for high quality machined components with low lead times has led to the automation of traditional engineering machinery such as centre lathes and milling machines. These Computer Numerical Control (CNC) machines are complex to operate and require the machine operator to have skills that are different to those required for manual machining. For example, they may need to be able to generate a part program and will spend more time on set-up and testing.

In this unit you will learn how to safely operate these machines whilst complying with relevant legal requirements. You will explore how CNC milling machines undertake advanced milling operations, the types of cutting tools and work holding devices that can be used and how to produce computer programs for the manufacture of components. This unit is a theoretical unit and learners are not expected to manufacture actual components.

Learning outcomes

In this unit you will:

1 Understand the principles of computer numerical control (CNC) milling operations

2 Understand how to interpret a component specification and produce an operational plan for its manufacture

3 Understand how to produce and test part programs for the manufacture of a milled component using manual programming and CAD/CAM procedures

Content

What needs to be learned
Learning outcome 1: Understand the principles of computer numerical control (CNC) milling operations

• Health and safety requirements associated with CNC milling operations:
  ○ duties of employers and employees under relevant legislation and regulations including HASAWA, PUWER, Control of Noise at Work Regulations, PPE Regulations, Manual Handling Regulations, Display Screen Equipment Regulations.
• Hazards associated with CNC operations and their control
  ○ the hazards associated with CNC milling operations including high speed operation, manual handling of work pieces and equipment, automatic operation of tool and work handling devices, lack of operator control or intervention, noise levels.
  ○ the control of hazards associated with CNC operations including operator training, emergency shutdown procedures, enclosed and interlocked guards, use of PPE.
• Main features of CNC milling systems:
  ○ the function of the main parts of a CNC system including the machine control unit, drive mechanisms, tool/workpiece interface, transducers, feedback, correction, Central Processing Unit (CPU), drive motors, quick change tooling, turret tools, cooling systems, display screens.
  ○ CNC machining parameters including datum points, designation of axes, definition of parameters using numerical coding, for example position, movement, spindle speeds, cutting tools, clamping.

What needs to be learned
Learning outcome 2: Be able to interpret a component specification and produce an operational plan for its manufacture

• Component specification:
  o interpretation of a detailed drawing to obtain set-up data including material type, reference points including edge datum and centre line datum, dimensions including external, internal, slot length and depths, tolerances, surface finish.
• Operational Plan:
  o zero datums
  o work holding equipment such as vices, direct clamping to the table, setting points.
  o sequence of operations including loading, machining, roughing, finishing, measurement, unloading.
  o calculation of cutter path coordinates, cutter compensation, cutting speeds, feed rates
  o grouping of similar operations.
  o tooling including milling cutters, milling tool holders, end mills including centre cutting and indexable, flutes, face mills, indexable drills, spot drills, collect chucks, drill chucks
  o special requirements relating to specific materials.
  o inspection and proving against specification.

What needs to be learned
Learning outcome 3: Understand how to produce and test part programs for the manufacture of a milled component using manual programming and CAD/CAM procedures
• Features of manual part programming software: o navigation around the user interface including menu bar, identification line, tool display window o system status including work/tool relationships including position, direction, amount of movement o rates of change of parameters including feed rates and spindle speeds o auxiliary functions including metric and imperial units, tool selection, cutting fluids o relevant CNC program codes and their functions, for example G codes, M codes, T codes o dimensional information including axis co-ordinates, absolute, incremental o block format, for example block number, program code, coordinates o special function program codes, for example measuring system, tool compensation, canned cycles. o subroutines including tool change, work holding, spindle speed, spindle direction. • Features of a CAD/CAM package: o typical hardware configuration including CAD workstation, data storage, hard copy equipment, network system. typical software packages for example, Solidworks, Catia, Autodesk Inventor, Denford VR milling/turning o typical data formats including extensions and proprietary formats, for example DXF, IGS, DWG, CDR, PCX, PLT. • Part program production and testing: o 3D geometric model using CAD software o selection of machining operations o selection of tooling o generation of CNC program using CAM software o simulation of tool changing and tool paths o program correction and editing o transfer of data files to CNC machine o Pre-manufacture run through using graphics display on CNC machine, prove program, dry run.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand the principles of computer numerical control (CNC) milling operations		
P1 Explain how a CNC milling machine differs from a manual universal milling machine	M1 Compare the use of CNC milling machine and a manual universal milling machine in relation to the manufacture of a given component	D1 Justify the use of a CNC milling machine over a manual universal milling machine in relation to the manufacture of a given component.
Learning outcome 2: Understand how to interpret a component specification and produce an operational plan for its manufacture		
P2 Describe the CNC milling set-up and the cutting tools needed to produce a component from given detail drawing	M2 Interpret the requirements from the given detail drawing to form a CNC milling operational plan for a given component	D2 Justify the order in which CNC milling operations are planned for a given component

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand how to produce and test part programs for the manufacture of a milled component using manual programming and CAD/CAM procedures		
P3 Produce and test a part program using manual CNC part programming for a given component drawing	M3 Assess the part program to ensure it effectively meets the requirements of the given component drawing	D3 Justify amendments to the part program in order to optimise the cycle time
P4 Use CAD/CAM software to produce a part program from a given component drawing	M4 Evaluate the benefits of using CAD/CAM software over manual CNC part programming	

Essential information for tutors and assessors

Resources

The special resources needed for this unit are: access to the internet and relevant engineering data tables. Learners would also benefit from access to engineering workshops containing CNC milling machines, associated cutting tools, work holding devices and ancillary equipment. They will also need access to CNC part programming and CAD/CAM software.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand the principles of computer numerical control (CNC) milling operations	A written report for which learners will need to produce a justification of the use of a CNC milling machine over a manual universal milling machine to produce a given component. As part of this, they will detail how a CNC milling machine differs from a manual universal milling machine in terms of the main features of the machines, their safe operation and the different forms of control.
2 Understand how to interpret a component specification and produce an operational plan for its manufacture	A practical task in which learners are provided with a detailed drawing and information about a component which they need to interpret. Learners will produce an operational plan to manufacture the product on a CNC milling machine and justify the sequence of operations detailed in their operational plan.

Learning outcome	Recommended assessment approach
3 Understand how to produce and test part programs for the manufacture of a milled component using manual programming and CAD/CAM procedures	A task in which learners must use the operational plan developed in learning outcome 2 to manually produce and prove a part program for the manufacture of the given component. In a further written task, learners will justify any amendments made to the program in order to meet the requirements of the component specification. Learners will then use a CAD/CAM package to produce the part programme for the same component before evaluating the benefits of using CAD/CAM software over manual part-programming.

Learning outcome 1 Understand the principles of computer numerical control (CNC) milling operations

For Distinction standard, learners will go beyond the comparison given for the merit standard and justify the use of a CNC milling machine over a manual universal milling to produce the given component, with detailed reasons. Learners should, where possible, support their justification using examples from their own workplace (D1).

For Merit standard, learners will go beyond the explanation given in the pass standard and will compare the benefits and limitations of using a CNC milling machine over a manual universal milling machine in order to manufacture a component from a given detailed drawing. They must also include details of the how the manufacture of the component will differ using each (M1). The given component must be sufficiently complex for manufacture using a CNC milling machine to be a sensible consideration.

For Pass standard, learners will explain how a CNC milling machine differs from a manual universal milling machine in terms of the main features of the machines, their safe operation and the different forms of control. As part of this, learners will also provide a brief explanation setting out the main points of the health and safety legislation and regulations pertaining to themselves and their employers in order to conduct CNC milling operations safely (P1).

Learning outcome 2 Understand how to interpret a component specification and produce an operational plan for its manufacture

For Distinction standard, learners will go beyond the production of an operational plan by providing details of the decisions they took when generating the said plan, with detailed reasons to support these decisions. As a minimum, the justification will relate to the sequencing of the machining operations (D2).

For Merit standard, learners will go beyond the description in the pass standard and will produce a comprehensive operational plan for the manufacture of the given component shown in the detailed engineering drawing. Learners will need to support their operational plan using additional evidence in the form of annotated drawings detailing proposed tooling paths as appropriate, annotated specification sheets and calculations to support machining decisions such as speeds and feed rates (M2).

For Pass standard, learners will give a clear account of how a CNC milling machine is to be set-up in order to produce a component using CNC milling techniques from a given detailed engineering drawing (component specification). They will also describe all of the types of milling cutters required to produce the component (P2).

Learning outcome 3 Understand how to produce and test part programs for the manufacture of a turned component using manual programming and CAD/CAM procedures

For Distinction standard, learners will produce a written report that justifies any amendments they have made to their original manual part program, with detailed reasons to support the changes to their work. For example, they may have amended it in order to reduce the run time and condense the number of steps and tool changes required (D3).

For Merit standard, learners will go beyond the requirements for the pass standard and will produce a written report that reviews their manually produced part program and assesses where improvements to it could be made before reaching a conclusion on how well it enables the component to be manufactured to the specification detailed in the given component drawing (M3). Learners will also evaluate the benefits and limitations of using CAD/CAM software to produce CNC programs over the use of using manual CNC part programming. They will need to draw valid conclusions to their arguments which are appropriately supported with detailed reasons and examples (M4).

For Pass standard, learners will produce and test a manual CNC part program from the operational plan developed during the assessment for Learning Outcome 2. They will generate annotations on their part program that explain the sequence of machining operations (P3)

Learners will also produce a part program for the same component using CAD/CAM software. Their evidence will include a range of annotated screenshots for both the manual programming and the programming using CAD/CAM software. (P4)

Unit 11: Applications of Computer Numerical Control in Engineering

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

There are three basic principles to CNC machining. These are: positional control of the cutting tool relative to a workpiece using axes coordinates, the setting of cutting speeds and control of other functions such as the application of cutting fluid. To do this, machine tools need to be loaded with a series of instructions which is acted upon in sequence. These instructions are called program code and in this unit learners will be shown how to produce a working program using an industry-standard language.

The unit will consider two aspects of CNC machining. First, learners will investigate machine tools that have an in-built computer system. These are set up by a skilled operator who interprets data taken from an operational plan and converts this into program code.

Learners will then look at machine tools which are downloaded with code generated by a remote computer system running computer-aided design/manufacturing (CAD/CAM) software. The advantage that this type of system has over the stand-alone CNC machine is that a full three-dimensional (3D) simulation of the machining process can be carried out before any cutting of material takes place. This is an important aspect of economic manufacture because incorrect machining of a component will result in lost production and additional costs.

The unit has a high practical content and learners are expected to manufacture actual components. Learners will follow the various steps in the CNC process, starting with interpreting drawings and choosing a suitable machining process, correct cutting tools and work holding devices. They will then write and prove a part program, machine the product and carry out dimensional checking against specification.

The final part of the unit investigates the integration and use of CAD/CAM in the CNC machining process. Learners will be given a drawing file containing details of a component that they will then use to produce a 3D image of the component. Its functionality is confirmed before moving on to the simulation of the machining process using CAM software.

Once the machining operation has been proven and any problems corrected, the data needed to control the movements of cutting tools and other machine operations is downloaded from the computer into the machine's control unit. Machining then takes place, with the program data saved for future use.

Learning outcomes

In this unit you will:

1 Understand the principles of computer numerical control (CNC) and machine structures

2 Be able to interpret a component specification and produce an operational plan for its manufacture

3 Be able to produce a part program and manufacture a component

4 Be able to use a computer aided design/computer aided manufacture (CAD/CAM) software package to generate a part program and manufacture a component.

Content

What needs to be learned
Learning outcome 1: Understand the principles of computer numerical control (CNC) and machine structures
• CNC principles: ○ system e.g. machine control unit, drive mechanisms, tool/workpiece interface, transducers, feedback, correction ○ datum points, e.g. machine, component ○ definition of parameters using numerical coding, e.g. position, movement, spindle speeds, cutting tools, clamping, application of coolant ○ CNC process, e.g. select machine, select tooling, identify machining sequence, calculate positional coordinates, calculate spindle speeds, programming, post-processing, setup sheet, verify and edit, store for future use. • Machine structures: ○ types, e.g. milling, drilling, turning centre, machining centre ○ designation of axes, e.g. 2 axis, 3 axis, x, y, z ○ motor and drive units, e.g. spindles, stepless drives, ball screw, stepper motors ○ transducers, e.g. positional, linear, rotary, analogue, digital, optical encoders, inductive, capacitive, magnetic ○ tooling e.g. modular, quick change, turret ○ tool transfer e.g. automatic, chain magazine, circular magazine ○ work holding, e.g. pallets, sub tables, rotary work changer, grid plate ○ swarf removal, e.g. chutes, chip controllers, conveyors ○ cooling, e.g. cutting fluid, cooling systems ○ computer hardware, e.g. keypad, display, Central Processing Unit (CPU), storage, cabling links, machine control unit (MCU) ○ computer software, e.g. programming language, CAD/CAM DXF files ○ safety, e.g. overloading the cutting tool, guards, light barriers, interlocks, operator safety.

What needs to be learned
Learning outcome 2: Be able to interpret a component specification and produce an operational plan for its manufacture

- Component specification:
  - detailed drawing.
  - material, e.g. steel, aluminium, polymer, other stable material
  - reference points, e.g. edge datum, centre line datum
  - dimensional, e.g. external, internal, centres distances, bore diameters, tolerances.
  - surface finish, e.g. Ra, Rz values.
- Operational plan:
  - zero datums
  - work holding, e.g. clamps, fixtures, chucks, vices, setting points
  - changing components, e.g. pallets, sub tables, rotary work changer, grid plate
  - sequence of operations, e.g. loading, machining, roughing and finishing operations, measurement, unloading
  - calculations, e.g. cutter path coordinates for intersections, polar centres, arc centres, cutter compensation, cutting speeds, feed rates; use of trigonometric ratios, e.g. sine, cosine, tangent; cutter speed ($\frac{\text{surface speed}}{\pi} \times$ cutter diameter); feed rate (feed per tooth × number of teeth × spindle speed)
  - grouping of similar operations
  - canned cycles, e.g. irregular pockets, geometric, hole patterns
  - tooling, e.g. cutters, drills, reamers
  - other reference data, e.g. cutting fluids, special requirements relating to specific materials.
  - inspection, e.g. first off proving against specification, on machine measurement; set up sheet and tool list.

What needs to be learned
Learning outcome 3: Be able to produce a part program and manufacture a component
• Part program: o user interface, e.g. menu bar, identification line, tool display window, system status o work/tool relationships, e.g. position, direction, amount of movement o rates of change, e.g. feed rates, spindle speeds; auxiliary functions, e.g. metric/imperial units, tool selection, cutting fluids, workpiece loading and holding, tool changing. o CNC codes e.g. block number, preparatory functions (G codes). o miscellaneous functions (M codes) o other letter addresses (arc centres, spindle speed, feed rate) o dimensional information, e.g. axis coordinates (x, y, z), absolute, incremental o words, e.g. modal, non-modal o block format, e.g. block number, G code, coordinates o special function G codes, e.g. movement system, measuring system, tool compensation, canned cycles, subroutine o M codes, e.g. coolant, tool change, work holding, spindle speed, spindle direction. • Manufacture: o post-processing, e.g. transfer of files/data between systems, download program to machine tool o pre-manufacture, e.g. run through using graphics display on machine tool, prove program, dry run, load workpiece, stepping, adjust feed rates o run program, e.g. machine workpiece, first off inspect and check against specification, store verified program for future use, quality monitor o shutdown.

What needs to be learned
Learning outcome 4: Be able to use a computer aided design/computer aided manufacture (CAD/CAM) software package to generate a part program and manufacture a component.

• CAD/CAM package:
  ○ hardware, e.g. CAD workstation, data storage, hard copy equipment, network system to download data to machine tools
  ○ software, e.g. Autodesk Inventor, Esprit, Solid Works, Edge CAM, Denford VR milling/turning; universal formats, e.g. extensions (such as DXF, IGS, AI, EPS, PLT, NC), proprietary formats (such as DWG, CDR, CDL, GE3, NC1, BMP, MSP, PCX, TIF).
• Part program: e.g. 3D geometric model using CAD software, select machining operations, select tooling, generate CNC program using CAM software, simulation of tool changing and tool paths in the machining process, correction and editing.
• Manufacture:
  ○ post-processing, e.g. transfer of files/data between systems, download program to machine tool
  ○ manufacturing, e.g. load and clamp workpiece, set tooling, initiate program cycle, machine workpiece, first off inspect and check against specification, store verified program for future use, quality monitor; shutdown.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand the principles of computer numerical control (CNC) and machine structures		
P1 describe the principles on which a machine tool operates when controlled by a CNC system		
P2 describe, with the aid of suitable diagrams, the structure of a given CNC machine type		
Learning outcome 2: Be able to interpret a component specification and produce an operational plan for its manufacture		
P3 interpret the specification for a given component and produce an operational plan for its manufacture	M1 assess the importance of producing an accurate and detailed operational plan for a component that is to be manufactured using a CNC machine tool	

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Be able to produce a part program and manufacture a component		
P4 produce a part program for a given component	M2 assess the importance of correct programming and setting up in order to produce a component to a required specification	
P5 manufacture a component using a two- or three-axis CNC machine		
Learning outcome 4: Be able to use a computer aided design/computer aided manufacture (CAD/CAM) software package to generate a part program and manufacture a component.		
use a CAD/CAM package to produce a part program from a given component detail drawing	M3 test the program assessing how it meets the requirements of the drawing	D1 compare the effectiveness of a CAD/CAM method of manufacturing a component to that of using CNC part programming
P7 manufacture a component on a CNC machine using a post-processed program generated using CAM software.	M4 assess how the manufactured component meets the requirements of the program.	D2 evaluate the cost benefits of using CAD/CAM software when programming CNC machines.

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- 2D/3D commercial CAD software and CAM software that integrates with the CAD package used for designing
- access to a two- or three-axis CNC machine tool
- access to a two- or three-axis machine tool which can be downloaded with data from a computer system

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand the principles of computer numerical control (CNC) and machine structures	An assignment requiring learners to demonstrate their knowledge of the underlying principles of CNC machines and CNC machine structures Learners complete two written tasks for which learners need to produce an explanation of the principles on which machine tools operate and a written description of CNC machine structure.
2 Be able to interpret a component specification and produce an operational plan for its manufacture	An assignment relating to practical task(s) carried out by the learner. Learners demonstrate understanding of how to interpret a detailed drawing in order to produce an operational plan to manufacture the component on a CNC machine. Learners assess the importance of an accurate and detailed plan. Learners are provided with a detailed drawing and information about a component that they need to interpret. Learners produce an operational plan to manufacture the product on a CNC machine. Learners explain the importance of an accurate and detailed plan.

Learning outcome	Recommended assessment approach
3 Be able to produce a part program and manufacture a component	An assignment relating to practical task(s) carried out by the learner. Learners are given a pre-produced operational plan for which they produce a part program and manufacture a component using three-axis machining.
4 Be able to use a computer aided design/computer aided manufacture (CAD/CAM) software package to generate a part program and manufacture a component.	An assignment relating to practical task(s) carried out by the learner. Learners are given a detailed drawing for which they write a part program. Learners then need to use their post-processed program to manufacture the component. Learners compare CAD/CAM to CNC part-programming and evaluate the cost benefits of CAD/CAM.

This unit is assessed through five assignments. To achieve a pass grade, learners need to have an understanding of the principles of CNC and be able to manufacture a component. It is not expected that they should be able to program and set up CNC machines at an expert level, and this should be taken into account when designing assignments.

Learning outcome 1: Understand the principles of computer numerical control (CNC) and machine structures

For Pass standard, Learners produce a written report. Evidence for P1 should be generic and not specific to a particular type of machine. There is a lot of material that learners will have access to and care should be taken to ensure the validity of the evidence they provide.

P2 relates to a given type of machine, details of which should be specified in the assignment brief. Some learners may be working in a CNC environment and if they have specialised knowledge about a particular machine tool they could use this towards their evidence for P2.

Learning outcome 2: Be able to interpret a component specification and produce an operational plan for its manufacture

Grading criteria P3 and M1 complement each other and are assessed through a second assignment. The assignment brief should provide learners with hard copy information about the component and a detailed drawing presented in printed form to an acceptable industry standard. The brief could also include a pro forma for setting out the operational plan, although learners working in a CNC environment may wish to use their own style of layout. Care should, however, be taken to ensure there are sufficient aspects of an operational plan covered by the content section for learning outcome 2. It must be remembered that a plan for CNC machining is different from one for traditional machining.

For Merit standard, learners' evidence should make reference to the operational plan produced for P3 but additional evidence drawn from wider sources should be included. It is expected that learners will consider who will use the plan and the full range of possible implications if there are omissions and/or errors in the plan, with specific examples.

For Pass standard,

Learners will correctly interpret the requirements of a component spec including materials, reference points, dimensions and surface finish. Their operational plan will describe how the CNC milling machine is to be set up to produce the component from the specification. Learners will support their plan with annotated drawings and specification sheets, calculations to support machining decisions such as speeds and feeds and trigonometric ratios to calculate coordinates and intersections will also be needed to support P3.

Learning outcome 3: Be able to produce a part program and manufacture a component

The third assignment should be designed around P4, P5 and M2. It will add realism if the same component is used for both pass criteria.

For Merit standard, learners consider the impact of correct programming and setting up on producing a required component, with detailed reasons and examples of what could happen if the programming were incorrect, reaching a valid conclusion. (M2)

For Pass standard, Three-axis machining would be the preferred option, using something like a vertical milling machine. As the assignment involves a lot of practical work, evidence presented for assessment should include screenshots, witness statements, observation records and annotated digital images.

Ideally the same component should be used for P4 and P5. Evidence can include screen shots and annotated digital images.

Learning outcome 4: Be able to use a computer aided design/computer aided manufacture (CAD/CAM) software package to generate a part program and manufacture a component.

The fourth assignment could cover P6, P7, M3, M4, D1 and D2. Evidence presented for assessment should include screenshots showing tool path simulation, witness statements, observation records and annotated digital images. They will obviously need to identify benefits and limitations of each approach and draw valid supported conclusions.

For Distinction standard, Learners who wish to gather evidence for D1 will probably want to use the component specification provided in the third assignment so that they can contrast the effectiveness of the two methods of programming. D1 is very specific and some of the evidence presented could relate to the tasks undertaken to achieve P4, P5, P6 and P7. (D1).

When writing about their experiences, learners should include an evaluation of their own effectiveness in using the two systems of manufacture. Factors to be considered might include something on how easy it was to learn the software packages, ease of program editing and the lead times needed to produce the components. Discussions with a manufacturing engineer who works for a company using both systems or which has moved from CNC part programming to an integrated CAD/CAM setup could be used as further evidence.

A written task will need to be given asking learners to compare the effectiveness of a CAD/CAM method of manufacturing a component to that of using CNC part programming.

A further task can be included to cover D2, in the form of evaluative writing supported by evidence gathered from published case studies. Learners should consider the effectiveness of CAD/CAM programming in the wider context and not just concentrate on the components that they have manufactured.

Because there are well documented examples of the cost benefits achieved by companies who use CAD/CAM software to program CNC machines, care must be taken to ensure that what the learner presents as evidence is authentic.

For Merit standard, M3 and M4 are logical extensions of P6 and P7 respectively requiring explanations of how the entities produced meet the original requirements.

For Pass standard, the starting point for P6 and P7 is a detailed drawing and this should be given to learners as a file which can be opened using CAD/CAM software. With the agreement of the tutor, some learners who are taking the CAD unit may wish to use a component that they have previously drawn, but it needs to be in a form that can be easily processed.

Unit 12 Specialist Machining

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Specialist machining techniques can be defined as those where the tool will not necessarily make contact with the workpiece or that do not rely upon mechanical energy. This unit introduces three specialist machining techniques: laser beam, electro-discharge and electro-chemical machining techniques and their applications. You will acquire an understanding of the characteristics of, and principal considerations for the use of these specialist techniques. You will learn how the techniques are set-up, safely operated and the parameters that must be managed during machining to prevent common errors and faults. You will study the typical faults and errors arising from the use of each technique.

Learning outcomes

In this unit you will:

1 Understand the selection and use of specialist machining techniques

2 Know how to carry out specialist machining techniques

3 Understand preventative maintenance for specialist machining techniques

Content

What needs to be learned
Learning outcome 1: Understand the selection and use of specialist machining techniques
• Laser beam machining: o characteristics: light amplification by stimulated emission of radiation, high-energy coherent (temporal and spatial) photons, meta-stable energy state, popular inversion, optical lenses, wave length ranges, result of the application of laser to work piece (e.g. melting and vaporisation of work material and finally material removal) o machining considerations: characteristic length o machine components: lasing medium, solid state (e.g. Ruby) or gas (e.g. Helium, Argon, axial flow, transverse flow, folded axial flow), flash tube (e.g. helical or flat), reflective mirror, lamp, capacitor, switching electrode, high voltage supply o benefits and limitations of laser beam machining: benefits (e.g. technique can be applied at a micro scale, no physical tool therefore no tool wear), limitations (e.g. not suitable for heat sensitive materials like aluminium glass fibre laminates, poor surface finish) o safety precautions: significant heat generated at the cutting face, classification of lasers, hazards associated with operation (e.g. risk to eyes) o application of technique: heat treatment, alloying, cladding, sheet metal bending, rapid prototyping, stereo-lithography, selective laser sintering material removal (e.g. drilling, cutting and trepanning), typically used on metals, plastics and ceramics. • Electro-discharge machining: o characteristics: electro-thermal technique using electrical energy to generate a spark to remove material, potential difference, dielectric medium (e.g. kerosene or deionised water), electrostatic forces, cold emission, ionisation energy, avalanche motion of electrons, heat flux, method of material removal (e.g. shock waves due to collapse of plasma channel following discontinuation of the application of potential difference) o machining considerations: establishing an electric field, connecting the tool to a negative terminal and the workpiece to a positive terminal

What needs to be learned
○ machine components: dielectric reservoir, pump and circulation system, power generation and control unit, working tank with work holding device, x-y table accommodating the work table, tool holder, servo system to feed the tool, power generator (e.g. resistance-capacitance type relaxation generator, rotary impulse type generator, electronic pulse generator) ○ benefits and limitations electrodischarge machining: benefits (e.g. flexible tool geometry), limitations (e.g. work material must be a conductor of electricity, positive ions impinge on the tool prompting tool wear, local high temperature at the workpiece surface can lead to surface hardening) ○ safety precautions: heat is generated at the cutting face ○ application of technique: creation of dies for jewellery, badges or coinage; small hole drilling; prototypes and production parts for the aerospace, automobile and electronics industries; typically used on high strength temperature resisting alloys • Electro-chemical machining: ○ characteristics: controlled anodic dissolution at atomic level of an electrically conductive work piece (anode) by a tool (cathode), electrolyte, flow of high current at low potential, ionic dissociation/electrochemical reaction, Faraday's Laws (e.g. first and second), electrochemical equivalence ○ machining considerations: selection of electrolyte to suit workpieces to be machined (e.g. neutral salt solution of sodium chloride for steel), sludge, managing potential drop (e.g. the electrode potential, activation over potential, ohmic potential drop, concentration over potential, ohmic resistance of electrolyte) ○ machine components: power supply, electrolyte filtration and delivery system, tool feed system, working tank ○ benefits and limitations of electrochemical machining: benefits (e.g. tool wear is zero, no direct contact between workpiece and tool so no forces and residual stresses, good surface finish, less heat is generated, can produce complex, concave and curved components), limitations (e.g. cannot be used on soft materials) ○ safety precautions: hydrogen gas evolves at the tool (cathode) and has the potential to be explosive, electrolyte poses risk of corrosion to the tool, work piece and equipment ○ application of technique: die sinking, profile and contouring, trepanning, grinding, drilling and micro-machining, typically used on hard materials (e.g. titanium, aluminides, Inconel, Wasaploy, metal alloys high in nickel, cobalt and rhenium)

What needs to be learned
Learning outcome 2: Know how to carry out specialist machining techniques
• Laser beam machining: ○ start-up and shut down of laser beam machine: : use of laser safety screen and safety glasses matching laser wavelength and intensity, automatic cut out switch ○ machining and tooling set up: managing the characteristic length, wavelength ranges, operation on continuous or pulsed mode ○ adjusting parameters in relation to machining outcomes: setting the power density for different focus lengths, cutting speed, output power, auxiliary gas • Electro-discharge machining ○ start-up/shut down of electro-discharge machine: selecting appropriate electrodes (e.g. graphite, tellurium copper, brass) ○ machining and tooling set up: material removal rate (e.g. dependant on thermal properties of the work material), geometry of tools, ensuring dielectric fluid provides an oxygen free machining environment ○ adjusting parameters in relation to machining outcomes: controlling the gap between the tool and the work piece in conjunction with managing the potential difference so an electric field is established • Electrochemical machining: ○ start-up and shut down of electrochemical machines: vertical and horizontal electrochemical machining ○ machining and tooling setting up: material removal rate (e.g. depends on atomic weight, valency and electricity conductivity of the work piece), feed to the tool, no feed to the tool ○ adjusting parameters in relation to machining outcomes: controlling the gap between the tool (cathode) and the workpiece (anode), setting the current rate for the desired rate of material removal.

What needs to be learned
Learning outcome 3: Understand preventative maintenance for specialist machining techniques
• Laser beam machining: ○ common faults and errors that occur: deformation of small holes when cutting, burring of the workpiece, incomplete cutting state of the laser ○ specific preventative measures: pulse perforation to achieve better surface finish when cutting small holes, maintaining purity of cutting gas and sufficient output power of the laser to guard against burring, ensure laser nozzle match with the plate thickness ○ Good housekeeping: types of proactive or planned maintenance, not storing flammable materials in the vicinity of laser machining tool. • Electro-discharge machining: ○ common faults and errors that occur: incorrect electrical field can lead to arcing and localised material removal, issues with surface finish, overcut and tapercut ○ specific preventative measures: maintaining spark at the tool surface to ensure uniform removal of material, dielectric fluid should be dielectric and thermal resistance so it does not break down too quickly. ○ good housekeeping: types of proactive or planned maintenance, cleaning and alignment of automatic wire threading system and guides, replacing and cleaning power contacts, calibration of brake/clutch roller, emptying wire collection box, replacing door and tank seals. • Electro-chemical machining: ○ common faults and errors that occur: potential for short circuiting due to the feed rate exceeding the rate of dissolution ○ monitoring performance: managing stray current and variance in electrical conductivity. ○ good housekeeping: types of proactive or planned maintenance, avoiding direct skin contact with electrolyte, maintaining adequate exhaust ventilation.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand the selection and use of specialist machining techniques		
P1 Describe the characteristics and components of the three specialist machining techniques	M1 Compare the benefits and limitations of the three specialist machining techniques	D1 Justify the application of a specific specialist machining technique to a given machined component
P2 Describe safe operation of the three specialist machining techniques		
P3 Describe the use of the three specialist machining techniques		
Learning outcome 2: Know how to carry out specialist machining techniques		
P4 Describe the machining set-up to produce a component from a given drawing using a specialist machining technique	M2 Assess the effectiveness of the specialist machining technique set-up to produce the required component	D2 Evaluate approaches that can be taken to improve the effectiveness of the specialist machining technique set- up for the given component
P5 Describe the specialist machining technique parameters that must be managed to ensure the component meets the requirements of the drawing		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand preventative maintenance for specialist machining techniques		
P6 Explain common faults and errors that can occur using the three specialist machining techniques	M3 Analyse the importance of implementing preventative measures and good housekeeping to minimise errors and faults during the operation of the three specialist machining techniques	D3 Evaluate the operational advantages of preventative measures and good housekeeping to minimise errors and faults during the operation of the three specialist machining techniques
P7 Explain preventative measures and good housekeeping to minimise errors and faults during the operation of the three specialist machining techniques		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- Access to a workshop with specialist machining equipment and appropriate materials.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand the selection and use of specialist machining techniques	Learners prepare a report, schematic diagram and an informative presentation, in either slide or video format, related to the characteristics, components, working principles, safe operation and use of the three specialist machining techniques. As part of this, they will also compare the benefits and limitations of the three specialist machining techniques and justify the application of a specific specialist machining technique to produce a given component.

Learning outcome	Recommended assessment approach
2 Know how to carry out specialist machining techniques	An assignment requiring learners to demonstrate their knowledge of how to carry out a specialist machining technique. Learners complete two written tasks for which they need to produce a description of the machining set-up required to produce a component from a given drawings, and the parameters that must be managed to maintain the required quality of the component during production. As part of this, learners will also assess the effectiveness of their specialist machining technique set-up to produce the required component and then evaluate approaches that can be taken to improve current set- up.
3 Understand the preventative maintenance of specialist machining techniques	A portfolio of written evidence and diagrams requiring learners to demonstrate their understanding of the common faults and errors associated with each specialist machining technique. Learners will prepare a guide describing the different common faults and errors, and the preventative measures and good housekeeping that can be implemented to prevent them for the different specialist machining techniques. As part of this, learners will analyse the importance of implementing, and evaluate the operational advantages of preventative measures and good housekeeping to minimise errors and faults during the operation of the three specialist machining techniques.

Learning outcome 1 Understand the selection and use of specialist machining techniques

For Distinction standard, learners will justify the application of a specific specialist machining technique to produce a given component. Learners should clearly cover within the justification why they consider the technique to be optimal to machine the given component, covering factors such as material, component features, tolerances, surface finish and quantity required (D1).

For Merit standard, learners will compare the benefits and limitations of the three specialist machining techniques i.e. laser beam, electrodischarge and electrochemical machining. Learners should comment upon the advantages and disadvantages of the use of the three different machining techniques considering factors such as safety, complexity of set-up, the range of materials that can be machined and the operations that can be carried out, tool life and the quality of outcomes (M1).

For Pass standard, the learner will describe the characteristics and components of the three specialist machining techniques. Learners should describe the working principles for each specialist machining technique and draw a schematic diagram of the key components of each technique (P1). Learners could also prepare an informative presentation in either slide or video format, describing the safe operation and use of the three specialist machining techniques. Learners must cover all three techniques separately and should focus on aspects such as the safety of the operator, controlling the heat generated, the materials that can be machined and the types of operations that can be carried out (P2, P3).

Learning outcome 2 Know how to carry out specialist machining techniques

For Distinction standard, learners will draw together all of their assessment evidence to evaluate approaches that can be taken to improve the effectiveness of the specialist machining technique set- up. For example, how feed rate and material removal rate can be optimised to achieve a fast high quality finish (D2).

For Merit standard, learners will assess the effectiveness of the specialist machining technique set-up to produce the required component. Learners will be expected to clearly demonstrate that they can accurately assess the current set-up to identify inefficiencies or where problems may occur relating to safety or the quality of the outcome (M2).

For Pass standard, learners describe the machining set-up to produce a component from a given drawing using a specialist machining technique and the parameters that must be managed to ensure the component meets the requirements of the drawing. Learners will give details of the different stages of set-up for the specialist machining equipment covering machining and tooling set-up and start-up and shut down procedures, for the component required (P4), and the parameters that can be adjusted before and during machining to ensure the final outcome is to specification (P5).

Learning outcome 3 Understand preventative maintenance for specialist machining techniques

For Distinction standard, learners will evaluate the operational advantages of preventative measures and good housekeeping to minimise errors and faults during the operation of the three specialist machining techniques. They will consider all the different factors, for each technique, and will judge the potential impact of adopting preventative measures and good housekeeping against a more haphazard approach. For example, they will consider some of the issues related to reactive or emergency maintenance rather than proactive or planned maintenance for each specialist machining technique (D3).

For Merit standard, learners will analyse the importance of implementing preventative measures and good housekeeping to minimise errors and faults during the operation of the three specialist machining techniques. They will arrive at valid conclusions on the importance of adequately completing them for each technique. It is expected that learners will consider wider issues related to, for example, machining lead times and non-value adding activities (M3).

For Pass standard, learners will explain common faults and errors that can occur using the three specialist machining techniques, as well as the preventative measures and good housekeeping necessary to minimise errors and faults during the operation of the three specialist machining techniques. For example, learners may refer to the difficulties with using laser beam machining for deep cutting, the production problems that are likely if the dielectric fluid for electro discharge machining is not replaced at regular intervals and keeping the working gap constant during electrochemical machining (P6, P7).

Unit 13: Computer Aided Drafting in Engineering

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Computer-aided drafting is fast becoming the primary means of communicating design information in many industry sectors, particularly in engineering and manufacturing. Two-dimensional (2D) CAD drawings and three-dimensional (3D) CAD data can be shared with computer numerical control (CNC) machines using computer-aided manufacturing (CAM) software. 3D models can be rendered to produce photo-realistic representations, or can be animated to produce moving views of products and components as they would appear in service. Additionally, models can be used to analyse features such as mass, volume and mechanical properties.

This unit will enable learners to produce a variety of CAD drawings, from single-part 2D components to complex 3D models. Advanced techniques, such as using pre-prepared symbols to construct circuit diagrams and assembly drawings, will provide opportunities for learners to develop their skills. Learners will investigate the use of CAD in industry, the hardware and software required and the links with other software packages. In doing this, learners will appreciate the advantages of CAD over more conventional methods of drawing production.

Finally, learners will generate 3D models, make comparison with 2D CAD drawings and evaluate the impact of this technology on manufacturing companies and their customers.

The unit as a whole provides an opportunity to carry out practical CAD activities using a full range of commands and drawing environments. In addition, learners will gain an understanding of the use and impact of CAD on the manufacturing industry.

Learning outcomes

In this unit you will:

1 Know the national and international standards and conventions that CAD drawings and design need to comply with

2 Understand the advantages of using CAD in comparison with other methods

3 Know about the software and hardware required to produce CAD drawings

4 Be able to produce and interpret CAD drawings

5 Be able to use CAD software to produce 3D drawings and views.

Content

What needs to be learned
Learning outcome 1: Know the national and international standards and conventions that CAD drawings and design need to comply with
• Requirements of current national and international standards and conventions: engineering drawing practice: BS 8888:2013, BS 5070-3 1988, BS EN 13622:2002, ISO standards. • Features of CAD drawings that need to comply with national and international standards: drawing sheet sizes and layouts, projection (first and third angle types of line, lettering and numbering, dimensioning, section cross hatching). • Standard representations: welding symbols, electrical symbols, pneumatic/hydraulic symbols, mechanical symbols.
Learning outcome 2: Understand the advantages of using CAD in comparison with other methods
• Advantages of CAD: quality; accuracy; time; cost; electronic transfer of information; links with other software, e.g. CAD/CAM, rendering software, animation software, finite element analysis (FEA). • Other methods: manual drafting; model making.
Learning outcome 3: Know about the software and hardware required to produce CAD drawings
• Software: operating systems; CAD software packages, e.g. AutoCAD, AutoCAD/Inventor, Microstation, Catia, Pro/ENGINEER, Solidworks; minimum system requirements, e.g. hard disk space, memory required, processor, video card. • Hardware: keyboard; mouse; other input devices, e.g. light pen, digitiser, joystick, thumbwheel; monitor; printer; other output devices, e.g. plotter, rapid prototyping; storage, e.g. floppy disk, hard disk, memory stick, CD, network.
Learning outcome 4: Be able to produce and interpret CAD drawings
• CAD drawings: orthographic projections; circuit diagrams, e.g. hydraulic, pneumatic, electronic; exploded/ assembly drawing; standards, e.g. BS 8888, BS 3939, BS 2917. • Commands: absolute/relative/polar coordinates; features, e.g. linetypes, grids, snaps, circle, text, hatching, dimensioning, layers/levels, colour; viewing, e.g. zoom, pan; inserting other drawings, e.g. symbols, blocks; modifying, e.g. copy, rotate, move, erase, scale, chamfer, fillet. • Interpret: determine properties of drawn objects, e.g. list, distance, area, volume.

What needs to be learned
Learning outcome 5: Be able to use CAD software to produce 3D drawings and views
• 3D environment: 3D views, e.g. top, front, side, isometric. • 3D models: 3D techniques, e.g. addition and subtraction of material, extrude, revolve, sweep, 3D coordinate entry (x, y, z), wire frame drawing, 2D to 3D (thickness, extrusion); surface models; solid models.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Know the national and international standards and conventions that CAD drawings and design need to comply with		
P1 describe the requirements of national and international standards and conventions relating to engineering drawing practice		
P2 explain which features of CAD drawings need to comply with national and international standard		
Learning outcome 2: Understand the advantages of using CAD in comparison with other methods		
P3 explain the advantages, compared to other methods, of producing drawings electronically using a CAD package		
Learning outcome 3: Know about the software and hardware required to produce CAD drawings		
P4 describe the software and hardware that are required to produce CAD drawings	M1 analyse the relationship between CAD and other software/hardware used in manufacturing	D1 justify the use of CAD in a manufacturing company

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 4: Be able to produce and interpret CAD drawings		
P5 produce 2D CAD detail drawings of five components that make up an assembly or sub-assembly to given standards, using appropriate commands	M2 assess how the range of commands used to produce CAD drawings can impact drawing production	
P6 produce a circuit diagram containing at least five components to appropriate standards, using appropriate commands		
P7 produce an assembly drawing and exploded view of an assembly or sub-assembly containing at least five parts, using appropriate commands		
P8 interpret the properties of an engineering component or circuit from a given CAD drawing		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 5: Be able to use CAD software to produce 3D drawings and views		
P9 construct a 3D CAD drawing as a surface and solid model.	M3 analyse how 3D CAD models can be used in the design process.	D2 evaluate the impact of the use of 2D and 3D CAD models on final design requirements.
P10 construct a 3D CAD drawing as a surface and solid model.		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- a suitably equipped IT facility with access to a printer/plotter.
- access to software with 2D and 3D capabilities, such as AutoCAD and Inventor. While general graphics packages would not be suitable, any CAD software capable of generating the evidence required for this unit would be acceptable.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Know the national and international standards and conventions that CAD drawings and design need to comply with	Learners to research national and international standards and relate to engineering CAD drawing practice. Learners produce report describing national and international standards and an explanation of CAD features that need to comply with these standards.
2 Understand the advantages of using CAD in comparison with other methods 3 Know about the software and hardware required to produce CAD drawings	Learners to research and compare the use of CAD with other methods and determine the software and hardware required to produce CAD drawings; in addition an investigation of how CAD links to other software and hardware and a justification of the use of CAD in manufacturing. Learners produce a report containing written responses about the use of CAD and alternative methods; in addition the software and hardware requirements of

Learning outcome	Recommended assessment approach
	a CAD system should be listed and explained. An explanation of how CAD links with other software and hardware should support a justification of the use of CAD in a manufacturing context.
4 Be able to produce and interpret CAD drawings	Learners to create an assembly drawing of at least five parts and detail CAD drawings of the five components; in completing the task learners should be able to explain how they used a range of commands in the CAD software to efficiently produce drawings. A portfolio of five component drawings and an assembly drawing containing the five individual parts; in addition a short report containing written responses and/or screen dumps explaining how a range of CAD commands were used to efficiently produce the completed drawings
5 Be able to use CAD software to produce 3D drawings and views	

Learning outcome 1: Know the national and international standards and conventions that CAD drawings and design need to comply with

One assignment could cover P1 and P2 and should be structured so that learners remain focused on the content of learning outcome 1.

For Pass standard, learners are expected to provide a clear account of the national and international standards and conventions (P1) and identify which features of CAD drawings need to comply with national and international standards with clear reasons why. (P2) While much of their research will be done using the internet, it is important that what they present is not just a simple cut and paste exercise. Evidence to support knowledge of which features of CAD drawings comply with national and international conventions could be generated by giving learners drawings which highlight the details required for meeting National and International conventions.

Learning outcome 2: Understand the advantages of using CAD in comparison with other methods

and

Learning outcome 3: Know about the software and hardware required to produce CAD drawings

For Distinction standard, learners should justify the use of CAD and will need to analyse other factors (for example disadvantages, costs, training requirements) to support its use (D1). This links with P3 and P4 as well as the M1 and M2 criteria. Learners should consider the relative merits of using CAD software. This could be as part of the case study outlined as possible evidence for the P3 criterion.

For Merit standard, learners will need to look beyond how drawings are produced and analyse their use and application. This will typically be through looking more closely at the relationship between CAD and other software, such as software used to order materials or to control production planning. Learners should explain how linking CAD to other software/hardware impacts on an organisation (for example improving production, reducing waste, reducing lead times). This will build on the evidence generated for P3 and enable the M1 merit criterion to be achieved.

For Pass standard, learners f give valid reasons for using CAD instead of more traditional drawing methods, including how CAD systems can be linked with other software (P3). Learners give a clear account of basic hardware and software requirements for operating a CAD system (P4).

Learning outcome 4: Be able to produce and interpret CAD drawings

and

Learning outcome 5: Be able to use CAD software to produce 3D drawings and views

For Distinction standard, learners will need to evaluate 2D and 3D drawings from a customer perspective (D2). This links directly with the P9 and M3 criteria. Learners will need to compare the impact on customers of producing drawings using 2D and 3D CAD and how customers might use the information produced.

For Merit standard, learners will assess how the range of commands impact on drawing production in terms of efficiency (for example speed, accuracy, repeatability, cost saving) (M2). This links with P5, P6 and P7. Leaners will assess in detail how 3D CAD models are used in the design process, for example by testing assembly parameters between mating components (M3).This links with the 3D activity in P9.

For Pass standard, learners' evidence should refer to a series of practical activities they have carried out. Evidence should be in the form of a portfolio, although it is likely that electronic files will be used for the majority of the assessment. Screen dumps can often be a good source of evidence to show the range of commands used during the development of the drawings.

The process evidence for these remaining pass criteria (P5 to P9) could be obtained from further assignments. Learners produce five separate CAD drawings of the components which make up an assembly or sub-assembly (P5). The full range of commands must be used and the drawings should be dimensioned to an appropriate standard.

These drawings could then be used to produce an assembly drawing and exploded view drawing (P7).

A further assignment is needed for learners to produce a circuit diagram with five components to appropriate standards using appropriate commands (P6). This might reflect learners' occupation or area of interest and should be assembled from symbols previously introduced by the tutor and/or externally sourced.

In this assignment learners interpret and provide a summary of the information contained in a given detail drawing or circuit diagram (P8).

The final assignment would require learners to produce a single 3D model using both surface and solid modelling techniques. This might be a 3D version of one of the part drawings used as evidence for the assembly and exploded view drawing. (P9)

Unit 14 : Precision Grinding Techniques

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Grinding is an abrasive machining technique that uses hard grits held in a matrix to remove material from a workpiece. It is the oldest of the basic machining processes and long before the advent of modern machinery, stones were used to sharpen scythes and kitchen knives.

In this unit you will learn about the continued importance of precision grinding techniques when shaping hard metal alloys like those used in drill bits or engine components, and how grinding can deliver unparalleled surface finish and dimensional accuracy for precision components. You will gain an understanding of the principles involved in abrasive grinding and how these are applied in a range of precision grinding techniques.

This unit provides the necessary background knowledge required for engineering technicians or apprentices involved in carrying out grinding techniques.

Learning outcomes

In this unit you will:

1 Understand the principles of grinding

2 Understand the use of different precision grinding techniques

3 Understand how to prepare for and undertake precision grinding techniques

Content

What needs to be learned
Learning outcome 1: Understand the principles of grinding

- Principles of material removal in abrasive machining including:
  - abrasive grain properties e.g. hardness, attrition, friability, geometry
  - action of abrasive grains on material surfaces e.g. ploughing, rubbing, cutting, chip formation.
  - waste (mix of dislodged abrasive gains and swarf).
- Characteristics of grinding wheels to include:
  - abrasive type e.g. silicon carbide, aluminium oxide, synthetic diamond
  - grain/grit size e.g. coarse, medium, fine, very fine.
  - bond material e.g. vitrified, resinoid, epoxy.
  - structure e.g. dense, open
  - grade e.g. soft, medium, hard.
  - rated/maximum operating speed
  - type e.g. straight, cylinder, tapered, recessed one side.
- Abrasive wheel markings to BS ISO 525
- Importance and effects of grinding process parameters including:
  - rotational speed
  - peripheral speed
  - cross feed rate
  - infeed rate
  - grinding fluids
  - grinding wheel characteristics.
- Process capability characteristics e.g. surface finish, dimensional accuracy, ability to machine extremely hard materials.
- Surface finish parameters e.g. ISO roughness grades, Ra, grit.
- Advantages of grinding over conventional milling and turning machining processes.
- Typical applications of grinding e.g. HSG drill bits, tool steel gauge plate, bearing rollers.

What needs to be learned
Learning outcome 2: Understand the use of different precision grinding techniques

• Grinding techniques including safe use of equipment, process characteristics and applications of off-hand grinding e.g. pedestal mounted or bench grinder.
• Precision grinding techniques including safe use of equipment, work holding, process parameters, characteristics and applications of:
  ○ cylindrical grinding (centred)
  ○ centreless cylindrical grinding e.g. through-feed, end-feed, in-feed.
  ○ surface grinding e.g. horizontal spindle and reciprocating table
  ○ creep feed grinding.

Learning outcome 3: Understand how to prepare for and undertake precision grinding techniques
• Interpreting engineering drawings and material specifications for components suitable for precision grinding. • Selection of precision grinding technique, abrasive wheel characteristics and process parameters to suit component requirements. • Use of calculations and reference tables to determine precision grinding process parameters. • Safety and equipment checks e.g. condition and true of grinding wheel, position of machine guards, personal protective equipment, emergency stop procedure. • Setting machine parameters e.g. rotational speed, cross feed rate, infeed rate, table travel distance, grinding fluid feed. • Mounting workpiece e.g. magnetic chuck, between head stock and tail stock centres, chuck. • Machine start-up procedure. • Monitoring and adjustment during grinding. • Safe stopping and workpiece removal. • Machine shut-down procedure and cleaning.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand the principles of grinding		
P1 Explain the characteristics of grinding wheels and their applications.	M1 Compare different grinding wheels in terms of their characteristics, use for different purposes and applications.	D1 Justify the selection of a grinding wheel used in a given industrial application.
P2 Explain the key process parameters used in grinding.		
Learning outcome 2: Understand the use of different precision grinding techniques		
P3 Explain the safe use of offhand grinding techniques.	M2 Compare off-hand and precision cylindrical and surface grinding techniques.	D2 Justify the selection of a precision grinding technique in a given application.
P4 Explain two precision cylindrical grinding techniques.		
P5 Explain two precision surface grinding techniques.		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand how to prepare for and undertake precision grinding techniques		
P6 Explain how to set up a precision grinding machine to safely to produce a component from a given drawing.	M3 Assess how the set-up and operation can affect component finish and accuracy when using a precision grinding technique.	D3 Justify the set up and operation of precision grinding techniques chosen to produce a component using a precision grinding technique.
P7 Explain the safe operation of a precision grinding machine to produce a component.		
P6 Explain how to set up a precision grinding machine to safely to produce a component from a given drawing.		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- access to at least one type of precision grinding machine (as defined in the unit content)
- examples of engineering drawings for components suitable for precision grinding

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand the principles of grinding	Learners compile a reference guide to the principles of grinding. This will include a detailed explanation of the characteristics and use of grinding wheels and the key process parameters used in precision grinding. They then discuss a case study where they are required to read the marks from a range of grinding wheels, compare their characteristics and applications and justify the use of one of these in a given industrial application. Learners produce a portfolio of evidence including: tabulated data, annotated images, notes and text.

Learning outcome	Recommended assessment approach
2 Understand precision grinding techniques	Learners compile an illustrated reference guide to describe in detail a range of grinding and precision grinding processes. They will use this to help explain the differences between the offhand techniques with which they are likely to be familiar and precision grinding techniques. Finally, they will explore a case study where a precision grinding technique must be selected for use in the manufacture of an engineering component. They will provide a fully justified explanation of their selection. Learners could produce a portfolio of evidence including: annotated, labelled photographs, sketches, diagrams, notes and text.
3 Understand how to prepare for and carry out precision grinding techniques	Learners provide an illustrated guide to setting up and operating a precision grinding machine safely to make a ground component. This includes the whole process from being provided with a component drawing through to shutting down the machine safely after use. The guide will include a discussion of how decisions made during the set up and operation of the machine can affect component finish and accuracy. Finally, the settings chosen to produce the component to the required dimensional accuracy and surface finish will be explored and justified. Learners could produce a portfolio of evidence including: annotated, labelled photographs, sketches, diagrams, notes and text.

Learning outcome 1: Understand the principles of grinding

For Distinction standard, learners justify why a specific grinding wheel is used in an industrial precision grinding application. This will be based on a detailed given scenario. Learners will focus on the characteristics of the grinding wheel and the process parameters and how they relate to the specifics of the product being ground. Learners justify why grinding is necessary and give detailed reasons for why more conventional processes like turning or milling are unsuitable. (D1)

Learners produce written evidence that is easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and will use correct technical engineering terms with a high standard of written language, i.e. consistent use of correct grammar and spelling.

For Merit standard, learners interpret the markings on **three** different examples of abrasive wheels used in precision grinding applications. Learners will compare the different grinding wheels effectively, perhaps using a table to summarise the technical information with additional explanatory notes providing a detailed comparison of characteristics. Learners will link each of the three grinding wheels to a suitable application and the necessary process parameters. For example, two wheels differing only in grit size will be used on similar materials to provide different material removal rates and surface finishes and a wheel with low grit/high feed rate could be used for basic surface finishing on gauge plate whilst a high grit/low feed rate might be used for final finishing on bearing rollers. (M1)

The comparisons will use accurate engineering terminology, for example there will be clear definitions of terms such as abrasive type and bond material when comparing different grinding wheels and detailed consideration of how grain/grit size affects surface finish in precision grinding processes. Overall, the evidence will be logically structured and cover the majority of the characteristics and process parameters mentioned in the unit content.

For Pass standard, learners will provide evidence that explains the effects of grinding wheel characteristics and process parameters used in grinding. For example, they will make connections between the abrasive grain type and its effectiveness in material removal to produce a suitable finish in a certain time. The evidence produced will relate to at least three applications, such as the finish grinding of a stainless steel shaft to ISO roughness grade N7. (P1, P2)

The explanations may have some omissions, but learners will mostly use engineering terms with accuracy. For example, there may be some lack of clarity in the definitions of terms such as abrasive type and bond material when explaining the characteristics of different grinding wheels or there may be cursory treatment of the importance of grain/grit size.

Learning outcome2: Understand the use of different precision grinding techniques

For Distinction standard, learners justify why a specific grinding technique is used in an industrial precision grinding application, be based on a detailed given scenario. Learners focus on the characteristics of the grinding technique and how they relate to the geometry and finish requirements of the component being machined. (D2)

Learners will produce written evidence that is easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and will use correct technical engineering terms with a high standard of written language, i.e. consistent use of correct grammar and spelling.

For Merit standard, learners will compare off-hand and precision cylindrical and surface grinding techniques including similarities and differences and advantages and disadvantages, perhaps by using a table. learners will provide evidence that indicates a good understanding of off-hand and both types of precision grinding techniques, for example by providing a detailed description of using an offhand grinder safely to accurately sharpen a drill bit, how through feed centreless cylindrical grinding uses a canted regulating wheel to feed a workpiece between the grinding wheels and work holding using a magnetic chuck in surface grinding and then explaining how these works and are used in practice. (M2)

The comparisons will use accurate engineering terminology, for example there will be clear and correct naming, labelling and annotation of machine parts.

Annotated diagrams or photographs will be used to support the written comparisons of the required techniques.

Overall, the evidence will be logically structured and provide good coverage of the grinding techniques with few technical inaccuracies or omissions.

For Pass standard, learners explain off-hand grinding techniques, including safe use of equipment, process characteristics and applications (P3)

Learners will also explain a cylindrical grinding technique and a precision surface grinding technique including safe use of equipment, work holding process parameters, characteristics and applications (P4, P5)

Learners will provide evidence that may be basic in parts, for example, providing a description of the process characteristics and parameters of cylindrical grinding without fully explaining their use and impact on the material removal process.

Labelled diagrams or photographs with annotation will be used to support written explanations of the required techniques. The explanations may have some omissions, but will mostly use engineering terms with accuracy., For example there may be some lack of clarity in the definitions of technical terms or in the naming and labelling of machine parts.

Learning outcome 3: Understand how to prepare for and undertake precision grinding techniques

For Distinction standard, learners will justify the set-up and operation chosen to produce the component using a precision grinding technique. Learners will include clear and detailed reasons for the selected set up and operation.

The justification for the set-up and operation of the grinding machine will relate the choice of initial process parameters and ongoing operational adjustments to the requirements of the component being machined e.g. justifying the use of grinding fluid to reduce friction, remove heat from the work zone and to increase material removal rate whilst maintaining surface finish. (D3)

Learners will produce written evidence that is easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and will use correct technical engineering terms with a high standard of written language, i.e. consistent use of correct grammar and spelling.

For Merit standard, learners assess how the set-up and operation of the grinding machine affects the component finish and accuracy. Learners will provide evidence that shows a good understanding of how to set-up and carry out a precision grinding technique, for example by providing a detailed explanation of how to mount a cylindrical workpiece between the grinding wheel and support roller when setting up for centreless grinding. The assessment will build on the explanations provided by considering the effects that changing the set-up or operation of the grinding machine will have on component finish and accuracy. For example, the effect of surface finish by reducing the set infeed rate for the final few finishing passes. (M3)

Learners use accurate engineering terminology, for example there will be clear and correct naming and labelling of machine parts. Annotated diagrams or photographs could be used to explain how machine parameters are set and how the machine is operated safely when grinding.

Overall, the evidence will be logically structured and provide good coverage of the practicalities of precision grinding with few technical inaccuracies or omissions.

For Pass standard, learners will provide evidence relating to one of the precision grinding techniques covered in the unit content. This will be appropriate for the production of a component using a given drawing.

Learners will explain how to set up the precision grinding machine to safely produce the component from the drawing. Learners will include the reasons for safety and equipment tests and for setting the machine parameters. (P6)

Learners will also explain how the precision grinding machine is operated safely to produce the component and will provide examples of where and how monitoring and adjustment may take during grinding. (P7)

Evidence may be basic in parts, for example, providing a description of setting the infeed rate on a surface grinding machine without fully explaining its effects.

The set up and operation may be summarised in a list of steps accompanied by additional explanatory notes. Explanations may have some inaccuracies relating to engineering terminology, for example there may be some lack of clarity in the definitions of technical terms or in the naming and labelling of machine parts.

Labelled diagrams or photographs with some annotations could be used to support written explanations of the safe set up and operation of the grinding machine.

Overall, the evidence will be logically structured and provide a good overview of how set-up and operation is carried out but will contain some technical inaccuracies or omissions.

Unit 15: Further Engineering Mathematics

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Mathematics can be used to evaluate the intended and actual performance of a product or system at every stage of its life cycle. For example, mathematics may be used during the design of a product to determine whether it performs to specification. Statistics may be used during manufacturing processes as part of the quality control (QC) system and to determine the in-service reliability of a product. Statistics can also be used to evaluate the vast amounts of data that can be gathered about products and customers using mobile communications and the Internet of Things (IoT).

In this unit, learners will use algebraic techniques to solve engineering problems involving sequences, series, complex numbers and matrices. You will investigate the use of statistics as a data-processing and analysis tool, for example applying techniques used by a quality assurance engineer to monitor the output from a manufacturing process.

As a future engineer, you will need to understand and develop skills to solve problems using algebraic and statistical procedures. These are transferable skills and you will use them to support your study of other units in this course. This unit will help to prepare you for an apprenticeship or for employment in a range of engineering disciplines as a technician. You could also progress to a higher-level course, such as a Higher National Diploma (HND) or a degree in an engineering discipline.

Learning outcomes

In this unit you will:

1 Examine how sequences and series can be used to solve engineering problems

2 Examine how matrices and determinants can be used to solve engineering problems

3 Examine how complex numbers can be used to solve engineering problems

4 Investigate how statistical and probability techniques can be used to solve engineering problems.

Content

What needs to be learned
Learning outcome 1: Examine how sequences and series can be used to solve engineering problems

Arithmetic and geometric progressions

- Definitions:
  - sequence as an ordered collection of numbers a, b, c, d
  - progression as a sequence that increases in a particular pattern, i.e. there is a constant relationship between a number and its successor
  - series as the sum of the values in a sequence a + b + c + d ...
  - terminology – first term *a*, last term *l,* connection by law.
- Routine operations involve:
  - arithmetic progression (AP):
    common difference *d*
    general expression for a sequence in AP: a, $(a + d)$, $(a + 2d)$, $(a + 3d)$, , $(a + nd)$
    nth term (last term) $l = a + (n - 1)d$
    sum of an AP to nth term (arithmetic series):
    $$s = a + (a + d) + (a + 2d) + \ldots + (l - d) + l = \frac{1}{2}n(a + l)$$
- geometric progression (GP):
  - common ratio *r:*
    general expression for a sequence in GP a, ar, ar^2, ar^3, ..., ar^n
- sum of a GP to nth term (geometric series):
  $s = a + ar + ar^2 + ar^3 + \ldots + ar^n = \frac{a(1-r^n)}{(1-r)}$
  - convergence
  - sum to infinity.
- Non-routine operations involve:
  - engineering applications, e.g. lathe spindle speeds, cost of deep drilling, depreciation costs of capital equipment, gear box ratios, manufacturing estimation.

Binomial expansion

- Definitions:
  - binomial expression that takes the form (a + b)n

What needs to be learned

- binomial theorem: when *n* is a positive integer

$$(a+b)^n = a^n + na^{n-1}b + \frac{n(n-1)}{2!}a^{n-2}b^2 + \frac{n(n-1)(n-2)}{3!}a^{n-3}b^3 + \ldots + b^n \text{ (a finite series)}$$

which can be written as $(a+b)^n = \sum_{k=0}^{k=n} {}_nC_k\, a^{n-k}b^k$ where ${}_nC_k = \frac{n!}{(n-k)!\,k!}$

alternative form $(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \ldots + x^n$

- binomial theorem when *n* is not a positive integer:
  $(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \ldots + x^n$ for $-1 < x < 1$ only (an infinite series)

Routine operations involve:

- construction of Pascal's triangle
- expansion of $(a + b)^n$ for positive values of *n* using Pascal's triangle.

Non-routine operations involve:

- expansion of $(1 + x)^n$ for non-positive integer values of *n* using the binomial theorem
- calculation of the *n*th term using the binomial theorem
- engineering applications, e.g. small errors, small changes, percentage changes, approximation of errors.

Power series

- Definitions:
  - a power series as $f(x) = a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots + a_nx^n$
  - a Taylor series as $f(x) = f(a) + f'(a)(x-a) + \frac{f^2(a)}{2!}(x-a)^2 + \ldots + \frac{f^{(n)}(a)}{n!}(x-a)^n$
- Routine operations involve:
  - a Maclaurin series as a Taylor series with $a = 0$
- convergence and divergence
  - conditions for convergence and divergence.
- Non-routine operations involve:
  - numerical value for e using a power series
    proof that $\frac{dy}{dx}(e^x) = e^x$ using series
- engineering applications, e.g. error in area or volume for small error in measurement of length, oscillator frequency for an electrical circuit if components have small errors in their values.

What needs to be learned
Learning outcome 2: Examine how matrices and determinants can be used to solve engineering problems

Matrices

- Definitions:
  - matrix type – element and order (row × column)
  - matrix terminology – element, row, column, order (row × column), equality, zero (null matrix), identity (unit) matrix, transpose, square, leading diagonal, triangular.
- Routine operations involve:
  - addition, subtraction, multiplication by a real number
  - inverse of a (2 × 2) matrix
  - solution of sets of simultaneous equations with two variables using inverse matrix methods.
- Non-routine operations involve:
  - multiplication of matrices
  - solution of sets of simultaneous equations with two variables using Gaussian elimination.

Determinants

- Definitions:
  - the determinant of a matrix as a useful value that can be computed from the elements of a square matrix, denoted by det(*A*) or $|A|$
    a singular matrix is one with the determinant $|A|$ = 0
  - Routine operations involve:
    the determinant of a (2 × 2) matrix $A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$ using $|A|$ = *ad* – *bc*

    the inverse of a two-dimensional matrix $A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$ using $A^{-1} = \frac{1}{|A|}\begin{pmatrix} d & -b \\ -c & a \end{pmatrix}$
- Non-routine operations involve:

  the determinant of a (3 × 3) matrix $A = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix}$ using

  $$|A| = a\begin{pmatrix} e & f \\ h & i \end{pmatrix} - b\begin{pmatrix} d & f \\ g & i \end{pmatrix} + c\begin{pmatrix} d & e \\ g & h \end{pmatrix}$$

What needs to be learned
○ use of Cramer’s rule to solve for sets of simultaneous equations with two variables ○ engineering applications, e.g. simultaneous linear equations with more than two variables (electrical circuits, vector arrays, machine cutter paths).

What needs to be learned

Learning outcome 3: Examine how complex numbers can be used to solve engineering problems

Complex numbers

- Definitions:
  - algebraic form (Cartesian, rectangular notation): (*a* + *jb*)
  - real part, imaginary part, *j* notation, *j*-operator, powers of *j*
  - modulus: $|a + jb| = \sqrt{a^2 + b^2}$
  - argument: $\arg(a + jb) = \tan^{-1}\left(\frac{b}{a}\right)$
  - polar form $r\angle\theta$; *θ* is usually expressed in radians but may be in another angular measure
  - complex conjugate of $y = a \pm jb$ as $y^* = a \mp jb$
- Routine operations involve:
  - placement of complex numbers on an Argand diagram
  - addition and subtraction in rectangular form
  - multiplication by a constant coefficient
  - conversion between rectangular and polar forms ($r \to p$ and $p \to r$) using trigonometry and a scientific calculator
  - multiplication and division of complex numbers in polar form.
- Non-routine operations involve:
  - multiplication in rectangular form
  - division in rectangular form using the complex conjugate
  - de Moivre's theorem: $(r\angle\theta)^n = r^n\angle n\theta$
  - engineering applications, e.g. vectors, electrical circuit phasor diagrams, algebraic form (Cartesian, rectangular notation): (*a* + *jb*)
  - real part, imaginary part, *j* notation, *j*-operator, powers of *j*
  - modulus: $|a + jb| = \sqrt{a^2 + b^2}$
  - argument: $\arg(a + jb) = \tan^{-1}\left(\frac{b}{a}\right)$
  - polar form $r\angle\theta$; is usually expressed in radians but may be in another angular measure
  - complex conjugate of $y = a \pm jb$ as $y^* = a \mp jb$

What needs to be learned

Learning outcome 4: Investigate how statistical and probability techniques can be used to solve engineering problems

Statistical techniques

- Routine operations involve:
  - discrete data, continuous data, ungrouped data, grouped data, rogue values
  - presentation of data: bar charts, pie charts, histograms, cumulative frequency curves
  - measures of central tendency (location): arithmetic mean, median, mode
  - measures of dispersion: variance, standard deviation, range and inter-percentile ranges
  - linear relationship between independent and dependent variables, scatter diagrams, approximate equation of line of regression *y* = *mx* + *c* represented graphically.
- Non-routine operations involve:
  - equation of linear regression line *y* = *mx* + *c* where

    $$m = \frac{N\sum_{1}^{N}(x_i y_i) - \sum_{1}^{N}(x_i)\sum_{1}^{N}(y_i)}{N\sum_{1}^{N}x_i^{\,2} - \left(\sum_{1}^{N}x_i\right)^2} \text{ and } c = \overline{y} - m\overline{x}$$

    $$\overline{x} = \frac{\sum_{1}^{N}x_i}{N} \text{ and } \overline{y} = \frac{\sum_{1}^{N}y_i}{N}$$

  - correlation coefficient using Pearson's correlation

    $$r_{x,y} = \frac{N\sum_{1}^{N}x_i y_i - \sum_{1}^{N}x_i \sum_{1}^{N}y_i}{\sqrt{N\sum_{1}^{N}x_i^{\,2} - \left(\sum_{1}^{N}x_i\right)^2} - \sqrt{N\sum_{1}^{N}y_i^{\,2} - \left(\sum_{1}^{N}y_i\right)^2}}$$

  - Use of spreadsheets and/or scientific calculators to calculate the equation of the line of regression and correlation coefficient, e.g. tabulating calculations, using trendline and CORREL() functions in a spreadsheet, or a standard scientific calculator.
  - Use of spreadsheets and/or scientific calculators to identify the most appropriate type of regression line, e.g. linear, logarithmic, exponential or variable power.

What needs to be learned

Probability distributions
• Routine operations involve:
  ○ normal distribution – shape and symmetry, skew, tables of the cumulative distribution function, mean, variance
  ○ normal distribution curve – areas under it relating to integer values of standard deviation.
• Non-routine operations involve:
  ○ confidence intervals for normal distribution and probability calculations.
Statistical investigation
• The use of appropriate mathematical methods to solve the given engineering problem.
• Engineering applications, e.g. inspection and quality assurance, calculation of central tendencies and dispersion, forecasting, reliability estimates for components and systems, customer behaviour, condition monitoring and product performance.
• Reflection on the problem-solving process and the solution obtained, making refinements if necessary.
• Presentation of the solution to the given engineering problem.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Examine how sequences and series can be used to solve engineering problems		
P1 solve given problems using routine arithmetic and geometric progression operations	M1 solve given problems accurately, using routine and non-routine arithmetic and geometric progression operations	D1 evaluate, using technically correct language and a logical structure, engineering problems using non-routine sequence and series operations, while solving accurately all the given problems using routine and non-routine operations
P2 solve given problems using routine power series operations	M2 solve given problems accurately, using routine and non-routine power series operations	D2 evaluate, using technically correct language and a logical structure, engineering problems using non-routine matrices, determinant and complex operations, while solving accurately all the given problems using routine and non-routine operations
Learning outcome 2: Examine how matrices and determinants can be used to solve engineering problems		
P3 solve given problems using routine matrices and determinant operations	M3 solve given problems accurately, using routine and non-routine matrices and determinant operations	

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Examine how complex numbers can be used to solve engineering problems		
P4 solve given problems using routine complex number operations	M4 solve given problems accurately, using routine and non-routine complex number operations	D3 evaluate the correct synthesis and application of statistics and probability to solve engineering problems involving accurate routine and non-routine operations.
Learning outcome 4: : Investigate how statistical and probability techniques can be used to solve engineering problems		
P5 solve an engineering problem using routine central tendency, dispersion and probability distribution operations	M5 solve an engineering problem accurately, using routine and non-routine central tendency, dispersion and probability distribution operations, providing an explanation of the process	D4 evaluate the correct synthesis and application of statistics and probability to solve engineering problems involving accurate routine and non-routine operations.
P6 solve an engineering problem using routine linear regression operations	M6 solve engineering problems accurately, using routine and non-routine regression operations, providing an explanation of the process.	

Essential information for tutors and assessors

Resources

The special resources needed for this unit are

- maths support websites, e.g. www.mathcentre.ac.uk/students/topics
- spreadsheet software and/or a scientific calculator such as Casio FX-85GT.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Examine how sequences and series can be used to solve engineering problems	An informal report containing the results of learners' analysis and calculation; carried out under controlled conditions.
2 Examine how matrices and determinants can be used to solve engineering problems	An informal report containing the results of learners' analysis and calculation; carried out under controlled conditions.
3 Examine how complex numbers can be used to solve engineering problems	An informal report containing the results of learners' analysis and calculation of measured and supplied data; carried out under controlled conditions. Where appropriate, processing of statistical data can be done by spreadsheet.
4 Investigate how statistical and probability techniques can be used to solve engineering problems	An informal report containing the results of learners' analysis and calculation of measured and supplied data; carried out under controlled conditions. Where appropriate, processing of statistical data can be done by spreadsheet.

Learning outcome 1: Examine how sequences and series can be used to solve engineering problems

For Distinction standard, learners demonstrate mastery in the application of algebraic techniques to the correct solution of given problems involving sequences and series. Where appropriate to the non-routine problems, learners will correctly and efficiently manipulate formulae and present reasoned and balanced evaluations.

Overall, the evidence will be easily understood by a third party with a mathematical background, who may or may not be an engineer. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions that model engineering situations. Small and large numerical values will be correctly presented in an appropriate format, for example engineering notation or standard form. Learners must demonstrate that they are able to work to specified numerical precision, as specified by the assessor, through the use of appropriate significant figures. (D1)

For Merit standard, learners accurately apply appropriate routine and non-routine operations (skills and methods) needed to solve given problems based on sequences and series.

Overall, the numerical work will be to an appropriate degree of accuracy, as specified by the assessor. For example, appropriate significant figures and decimal places. Solutions must be structured logically and the correct mathematical terminology and relevant units will be used, with limited number of minor errors or omissions in non-routine operations. (M1, M2)

For Pass standard, learners demonstrate the correct use of routine operations (skills and methods) when working with given problems based on sequences and series.

Overall, minor arithmetic and scaling errors are acceptable, as are 'carry through' errors, provided that the basic method is sound. For example, a term in a sequence may be incorrectly calculated but the value used correctly in subsequent calculation of the series, affecting the final value. Learners will demonstrate an appreciation of the need for the correct use of units but there may be errors in their application. There will also be evidence of simple checks to determine if numerical answers are 'reasonable'. (P1, P2)

Learning outcome 2: Examine how matrices and determinants can be used to solve engineering problems

and

Learning outcome 3: Examine how complex numbers can be used to solve engineering problems

For Distinction standard, learners demonstrate mastery in the application of algebraic techniques to the correct solution of given problems involving matrices, determinants and complex numbers. Where appropriate with the non-routine problems, learners will correctly and efficiently manipulate formulae and present reasoned and balanced evaluations.

Overall, the evidence will be easily understood by a third party with a mathematical background, who may or may not be an engineer. Learners will use mathematical methods and terminology precisely and apply relevant units when working with mathematical expressions that model engineering situations. Small and large numerical values will be correctly presented in an appropriate format, for example engineering notation or standard form. Learners must demonstrate they are able to work to specified numerical accuracy through the use of appropriate significant figures, as specified by the assessor (D2)

For Merit standard, learners accurately apply appropriate routine and non-routine operations (skills and methods) needed to solve given problems based on matrices, determinants and complex numbers.

Overall, the numerical work will be to an appropriate degree of accuracy, as specified by the assessor. For example, appropriate significant figures and decimal places. Solutions must be structured logically and the correct mathematical terminology and relevant units will be used, with limited number of minor errors or omissions in non-routine operations. (M3, M4)

For Pass standard, learners demonstrate the correct use of routine operations (skills and methods) when working on given problems based on matrices, determinants and complex numbers.

Overall, minor arithmetic errors are acceptable, as are 'carry through' errors, provided that the basic method is sound. Learners will demonstrate an appreciation of the need for the correct use of units but there may be errors in their application. Learners will include evidence of simple checks to determine if numerical answers are 'reasonable'. (P3, P4)

Learning outcome 4: Investigate how statistical and probability techniques can be used to solve engineering problems

For Distinction standard, learners demonstrate mastery in the application of the processing and evaluation of statistical data generated from engineering sources. The identified problems must be sufficiently complex to allow learners to apply both routine and non-routine operations (skills and methods) to their solution. For example, in terms of measures of central tendency and dispersion learners may evaluate one set of measured and four sets of equivalent historical data such as dimensional data from a machining operation or reliability data sourced from products in service. Before starting to process any data, learners will establish that the data sets are large enough to enable reliable analysis to be carried out. For regression, they will propose a theoretical relationship between two variables, collect data, calculate a mathematical relationship between dependent and independent variables using appropriate analytical and graphical methods, and reflect on the accuracy of the initial proposal for a linear and a non-linear relationship.

Overall, the evidence will be easily understood by a third party with a mathematical background, who may or may not be an engineer. There will be correct use of mathematical terminology and the application of relevant units. Learners will work to specified numerical precision, as determined by the assessor or that are appropriate for their chosen problems being solved, through the use of appropriate significant figures or decimal places. Small and large numerical values will be correctly presented in an appropriate format, i.e. engineering notation or standard form. (D3)

For Merit standard, learners present accurate solutions for engineering problems related to measures of central tendency, dispersion and probability distribution, breaking them down into planned stages to obtain solutions. They will apply appropriate routine and non-routine operations (skills and methods) needed to process statistical data accurately. For example, tabulation of data, graphical presentation, accurate calculations of mean and standard deviation comparing measured values with historical data, accurately produced annotated scatter graph (with chart title, axis titles including units and gridlines) and calculation of line of regression and correlation coefficient for a linear relationship and regression line for a non-linear relationship.

Overall, the numerical work will be to an appropriate degree of accuracy, as specified by the assessor or appropriate for the chosen problems being solved. Solutions will contain an explanation of the process that will be logically structured, and the correct mathematical terminology and relevant units will be used. There may be limited number of minor errors or omissions in non-routine operations. For example, when evaluating sampled dimensional data from a machining operation, learners may determine the mean and standard deviation for a sample and find a degree of correlation between samples, but not draw conclusions from, the values. (M5, M6)

For Pass standard, learners present the solutions of engineering problems involving measures of central tendency, dispersion and probability distribution. Ideally, they will research their own problems but if this is not possible then they can be given to learners. The solutions may not be complete and there may be some inaccuracies or omissions but there should be evidence of some proficiency of method. Learners will apply the appropriate routine operations (skills and methods) needed to process statistical data. For example, when evaluating sampled dimensional data from a machining operation, learners will present data appropriately and determine routine values such as the mean and standard deviation for a sample but may not compare the values with historical data. They will tabulate measurements and present data in a scatter graph and they may estimate the line of regression graphically.

Overall, the report should be logically structured. It may contain some arithmetic errors that 'carry through', for example the value of the mean of a set of sampled dimensional data from a machining operation may be incorrect, but that value used correctly to find the standard deviation. The methods chosen may not be optimal but the chosen statistical methods should be applied correctly. Minor errors and omissions are acceptable. For example, the axis titles on a scatter graph may be missing units. There will be an appreciation of correct use of units but there may be errors or inconsistency in their application. Learners will include evidence of simple checks to determine if numerical answers are 'reasonable'. (P5, P6).

Unit 16: Organisational Efficiency and Improvement

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

In this unit, learners will gain an understanding of continuous improvement in their sector and identify areas in production where lean working could be used to aid the company. They will learn about quality control methods used in industry and understand the key factors required to remain competitive in the market.

Learners will understand the importance of human resource management in terms of building successful teams and the effect this can have on recruitment and retention of employees.

Learning outcomes

In this unit you will:

1 Understand production activities

2 Understand application of quality control and quality assurance

3 Understand organisational improvement techniques and competitiveness

4 Understand personal rights and responsibilities in an organisation.

Content

What needs to be learned
Learning outcome 1: Understand production activities
• Types of production: e.g. mass; flow; automated; batch; one-off • Considerations: market requirements; design of product; plant and equipment availability; plant and equipment layout; personnel; production control; quality control; cost • Methods and application of cellular and just-in-time (JIT) production: relation to modern production requirements; application of push and pull types of production to meet company and customer needs and expectations • Stages of production planning: scheduling, loading, dispatching (coordination of pre-production activities); requirements, e.g. engineering drawings, technical data, personnel, machinery/tools, components, materials, consumables • Process charts: e.g. flow charts/diagrams, Gantt charts; symbols used in process charts

What needs to be learned
Learning outcome 2: Understand application of quality control and quality assurance
• Quality control and assurance: o meaning of 'quality control' and 'quality assurance' o fitness for purpose, e.g. meeting customer expectations o purchasing o production planning and procedures for quality assurance o manufacture (process control) o final inspection and dispatch o Statistical Process Control (SPC), e.g. measuring quality/performance, document control as an integral part of quality assurance, records of the correct operation o types and the purpose of sampling, e.g. spot check, random sampling, process sampling, batch sampling o mean time between failures (MTBF) in the context of sample size and frequency. • Inspection: o checking every stage for deviation from design specification o adjustments that need to be made o stages of inspection, e.g. goods inward, during production (process control), final inspection o role of the inspector in checking compliance with quality standard and procedures o quarantine area to store defective work. • BS EN ISO 9001: internationally recognised quality assurance standard; role of the quality manual and process/procedures manual; internal/external audits. • Quality manager: relationship with other managers/departments in the company; considerations to be made when developing a quality plan, e.g. quality requirements (customer expectations), allocation of responsibilities. • (at all levels), the setting up of systems to measure quality and report progress, identification and calibration of quality equipment, ability to take corrective actions where necessary. • Total quality management (TQM): main principles and goals; advantages of adopting TQM, e.g. competitiveness in the market, enabling growth and longevity, reducing stress, building teams, partnerships and cooperation.

What needs to be learned
Learning outcome 3: Understand organisational improvement techniques and competitiveness
• Business Improvement Techniques (BIT): principles of lean manufacture, e.g. removal of waste of all kinds (time, motion, inventory, poor cost of quality), stimulating productivity and quality; use of value-added processes. • Kaizen as a philosophy that encompasses continuous improvement; just in time (stockless production or lean production), e.g. manufacturing to order not to stock; Kanban inventory control. • Productivity: meaning of the term 'production'; benefits to the company of increasing productivity; company, e.g. multinationals, nationals and regional. • Small and Medium Enterprises (SMEs) and sole traders; managing the production process, e.g. layout of the production area, batch production, synchronisation, lead-time. • Continuous improvement: meaning of 'continuous improvement'; continuous improvement cycle (plan, do, check, and action); benefits gained; flexible working and multi-skilling; importance in the national and global marketplaces, e.g. multinationals, nationals, SMEs and sole traders. • Teamwork: roles in a team, e.g. leaders, doers, thinkers, carers; balance in a team; what individuals bring to a team; team building; communication in the team.
Learning outcome 4: Understand personal rights and responsibilities in an organisation
• Organisational documentation and employment legislation: documentation, e.g. contracts of employment, staff handbook; personnel records, grievance procedures; appraisals; disciplinary procedures; legislation, e.g. Employment Rights Act 1996, Working Time Regulations 1998, Health and Safety at Work etc. Act 1974, Data Protection Act 1998, Equal Opportunities Act 2010, Human Rights Act 1998, Equality Act 2010. • Development and progression opportunities: company training programmes; apprenticeships; organisational training opportunities; promotion; transfer; higher education; professional qualifications. • Roles of representative bodies: e.g. trade unions, professional bodies, employers' organisations (EEF, the manufacturers' organisation); industry training support. • Investors in People (IiP) national standard: four key principles – commitment, planning, action and evaluation; how organisations acquire IiP status.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand production activities		
P1 explain the different types of production	M1 compare the advantages and disadvantages of different types of production	D1 justify the selection of a production type for a given process
P2 describe the requirements that need to be considered when selecting a type of production		
P3 describe the different stages of production planning		
P4 explain how to apply typical process charts to production planning		
Learning outcome 2: Understand application of quality control and quality assurance		
P5 define the terms 'quality control' and 'quality assurance'	M3 assess the importance of using a structured approach for quality control and quality assurance	D2 evaluate a quality management process and make suggestions for improvement
P6 describe the role and stages of inspection activities		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P7 explain the application and content of the BS EN ISO 9000 series of standards		
P8 explain the role and responsibilities of the quality manager		
P9 describe the requirements of quality planning		
P10 describe the principles of total quality management (TQM)		
Learning outcome 3: Understand organisational improvement techniques and competitiveness		
P11 explain the terms Lean Manufacture, Kaizen, just-in-time and Kanban and their overall advantages	M3 assess the consequences for an organisation of not maintaining continuous improvement standards	D3 evaluate a production process and identify where improvements can be made to increase productivity and organisational competitiveness.
P12 explain the importance of improving organisational productivity		
P13 describe the need for continuous improvement to ensure organisational competitiveness		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P14 describe the key requirements for managing the production process		
P15 explain the importance of teamwork and the individual's contribution to effective teamwork		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 4: Understand personal rights and responsibilities in an organisation		
P16 explain the key features of employment legislation in relation to personnel rights and responsibilities	M3 assess the consequences for an organisation of not maintaining a continuous improvement approach	
P17 describe the personnel opportunities for development and progression that are available in the workplace		
P18 describe the role of the representative bodies in the engineering sector that support personnel and organisations		
P19 explain the implications that 'Investors in People' has on an organisation and its personnel.		

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- Case study into quality management of a sample company for learners with unsuitable employers to study their own company.
- Evidence from previous employment law cases to allow learners to identify the importance of a company abiding by the law.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand production activities	A company decides to manufacture a product. Learners analyse the possible types of production to produce it and identify the most suitable, justifying their selection.
2 Understand application of quality control and quality assurance	Learners analyse existing quality management procedures in a company (or their own company if suitable) and use the data found to suggest improvements.
3 Understand organisational improvement techniques and competitiveness	Learners identify the most common production methods used by companies (and their own company if appropriate) and analyse the impact that these processes have had on productivity.

Learning outcome	Recommended assessment approach
4 Understand personal rights and responsibilities in an organisation	Learners analyse their workplaces' employment contracts and processes, alongside existing cases brought against companies to analyse the importance and effect of the law and union's role in defending workers' rights. Learners will identify the importance of investment in the workforce, how companies obtain IiP and what effect that has on employment.

Learning outcome 1: Understand production activities

The evidence to satisfy the learning outcome 1 could be achieved by means of a written task based upon a given product that needs to be manufactured.

For Distinction standard, learners justify their choice of production type, supporting their work with detailed reasons. (D1)

For Merit standard, learners compare at least two possible production types, explaining the main features of each and their advantages and disadvantages. (M1)

For Pass standard learners identify a range of production processes that could be used to manufacture a product and explain the underlying principles behind them with valid reasons (P1).

Learners identify the customer requirements for a given type of product and describe how these requirements will impact on the selection of a specific production method. (P2)

Learners describe the key stages in production planning and apply these to produce their production plan for the given product. Learners explain the need and importance of process charts in the plan to identify key stages in the production. (P3, P4)

Learning outcome: 2: Understand application of quality control and quality assurance

This could be linked to a case study, based around a company visit if possible.

For Distinction standard, learners draw their evidence together to evaluate the effectiveness of a quality management process used in the company, suggesting improvements with valid reasons (D2).

For Merit standard, learners consider the underpinning procedures that link quality control and quality assurance and assess the importance of structure in the quality procedures (M2).

For Pass standard, learners define the terms 'quality control' and 'quality assurance' (P5) and give details of the content of the BS EN IWO 9000 series of standards and explain how they are applied in the company with valid examples. (P7)

Learners give a clear account of the requirements of quality planning and the principles of TQM, including its main goals and advantages (P9, P10)

Learners give a clear account of the role and stages of inspection activities and the responsibilities of the quality manager within the company. (P6, P8).

Learning outcome 3: Understand organisational improvement techniques and competitiveness

For Distinction standard, learners draw their evidence together to evaluate a production process and reach a detailed and valid conclusion on improvements to the production process (D3).

For Merit standard, learners assess the consequences for an organisation of not adopting a continuous improvement approach, for example, the impact of not removing all forms of waste, not reducing non-value adding processes and not enhancing the skills of staff (M3).

For Pass standard, P11 and P12 can be achieved through a written analysis of the different types of production processes and their advantages in improving productivity. This would then lead to a description of the importance of continuous improvement for P13.

Learners define the terms 'lean manufacture', 'Kaizen', 'just-in-time' and 'Kanban' and explain the main advantages of each with reasons. Learners give valid reasons for improving organisational productivity and a clear account of continuous improvement and how it improves organisational competitiveness (P11, P12, P13).

Learners give a clear account of key requirements for managing a given production process and give reasons for the importance of team work to productivity with examples of how individuals contribute to effective team work. (P14, 15).

Learning outcome 4: Understand personal rights and responsibilities in an organisation

For Merit standard, learners consider in detail the effects of not adhering to employment legislation in relation to personal rights and responsibilities, drawing a valid conclusion. For example, learners could use case studies to demonstrate the impact of different forms of discrimination in the workplace (M4).

For Pass standard, the achievement of P16 should be tied to an analysis of learners' own workplace human resources department. Learners give reasons for the key features of employment legislation in relation to personnel rights and responsibilities, including why it is important for companies to follow the law. This could be linked to the importance of representation from bodies such as workers' unions for P18.

Learners give a clear account of the role of representative bodies in the engineering sector that support personnel and organisations.

P17 and P19 can be achieved through research into why companies should continually develop their staff and the effect that Investors in People has on encouraging employment and development. Learners give a clear account of personnel opportunities for development and progression that are available in the workplace. They then give examples of the implications that 'Investors in People' has on an organisation and its personnel.

Unit 17: Engineering Inspection and Quality Control

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

Inspection and quality control are essential to all engineering manufacturing operations. The quality control checks and measurements made during and after manufacture ensure that dimensions of the finished component are within acceptable tolerances. Only then will they fit together with other parts, function as intended and comply with all the requirements of their design specifications

In this unit you will learn about measurement systems and how to interpret dimension and tolerance information found on engineering drawings. You will also look at the tools and equipment used in the accurate and precise measurement of engineering component characteristics and how quality control procedures are planned and carried out.

Learning outcomes

In this unit you will:

1 Understand measurement systems and tolerancing

2 Understand the use and calibration of measuring devices

3 Understand how to plan and carry out quality control procedures

Content

What needs to be learned
Learning outcome 1: Understand measurement systems and tolerancing
• Units of measure commonly encountered in engineering applications including: o linear e.g. m, mm, µm o angular e.g. decimal degrees, radians o surface finish e.g. Ra, D, Rmax. • Dimensional tolerancing to include: o standard representation and symbols e.g. conventional, geometric o use and interpretation of tolerancing on engineering drawings e.g. linear, angular, straightness, flatness, circularity, cylindricity, concentricity, perpendicularity o standards e.g. BS 8888. • Limits and fits to include: o standard representation e.g. alpha numeric code o use and interpretation of limits and fits on engineering drawings e.g. tolerancing holes and shafts, clearance, transition, interference. • standards e.g. ISO 286.
Learning outcome 2: Understand the use and calibration of measuring devices
• Characteristics, use, calibration and applications of measuring devices including: o linear e.g. rules, calipers, micrometers, height gauges o angular e.g. bevel protractor, sine bar o alignment e.g. straight edge o comparators e.g. dial test indicators (DTI), lever type, Sigma type o gauges e.g. angle, radius, ring, plug thread, go/no-go o reference standards e.g. slip gauges, angle gauges o ancillary equipment e.g. surface plate, DTI stand o surface roughness tester.

What needs to be learned

• Calibration and record keeping including:
  o national, reference and working standards
  o traceability
  o calibration procedures e.g. BS870:2008
  o calibration periods
  o equipment marking and record keeping.
• Causes of measurement error, their effects and precautions used in their prevention e.g. calibration error, dirt and grease, effects of heat, instrument damage, cosine error, incorrect use, incorrect reading.

Learning outcome 3: Understand how to plan and carry out quality control procedures

• Inspection plans to include:
  o sampling e.g sample size, sample selection
  o interpretation of component specifications and engineering drawings e.g. identification of critical parameters, tolerance limits, inspection criteria
  o measuring equipment e.g. selection, suitability, precision, calibration status
  o sequence of operations e.g. step by step plan, flow chart, procedure
  o recording results e.g. raw data, inspection record sheets
  o reporting e.g. data processing, tables, charts, analysis.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand measurement systems and tolerancing		
P1 Interpret correctly geometric tolerances and limits and fits.	M1.Analyse the principles of conventional and geometric tolerancing using examples	D1 Evaluate the importance of accurate interpretation of tolerancing information using examples.
Learning outcome 2: Understand the use and calibration of measuring devices		
P3 Explain the characteristics and use of measuring devices in engineering.	M2 Compare two measuring devices used in engineering	D2 Justify the selection of measuring devices for two contrasting applications.
P4 Explain the calibration of a given measuring device		
P5 Explain causes of error when using measuring devices, possible consequences of error, and how these are prevented.		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Understand how to plan and carry out quality control procedures		
P6 Develop a clear inspection plan for a given scenario.	M3 Develop a comprehensive inspection plan for a given scenario, explaining each element.	D3 Justify each element of an inspection plan developed for a given scenario.

Essential information for tutors and assessors

Resources

The special resources needed for this unit are:

- access to a range of measuring devices (as defined in the unit content)
- examples of engineering drawings where conventional tolerances, geometric tolerances and limits and fits are shown.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

Learning outcome	Recommended assessment approach
1 Understand measurement systems and tolerancing	Learners compile a reference guide on measurement systems and tolerancing, which includes a detailed explanation of the standard symbols, codes and other indicators found on engineering drawings and examples showing the correct interpretation of given tolerances and limits. A written evaluation of the importance of interpreting this information correctly, and the consequences of not doing so would end the guide. Learners could produce a written report containing annotated diagrams, examples of engineering drawings, notes and text.

Learning outcome	Recommended assessment approach
2 Understand the use and calibration of measuring devices	Learners compile an illustrated reference guide to describe in detail a range of measuring devices and explain their characteristics, uses, calibration and potential sources of error, the possible consequences of error and how error is prevented. They then compare two measuring devices and justify their use in two differing applications. Learners will produce a portfolio of evidence including: annotated, labelled photographs, sketches, diagrams, notes and text.
3 Understand how to plan and carry out quality control procedures	Learners provide a guide on how to develop an inspection plan, which explains the different elements and how they are determined. They will then apply this knowledge by developing a comprehensive inspection plan for a given scenario, justifying the choices made in each step as they do so. Learners produce a portfolio of evidence including: a written guide, an inspection plan, annotated engineering drawings, inspection record sheets.

Learning outcome 1: Understand measurement systems and tolerancing

For Distinction standard, learners evaluate why accurate interpretation of tolerancing information is important and focus on the consequences of getting it wrong. They include illustrated examples involving conventional tolerancing, geometric tolerancing and limits and fits. (D1)

Learners will produce written evidence that is easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and will use correct technical engineering terms with a high standard of written language, i.e. consistent use of correct grammar and spelling.

For Merit standard, learners examine the principles of conventional and geometric tolerancing and limits and fits with clear examples of the use of each. Learners will provide a tabulated summary of symbols, codes and abbreviations that must be accompanied by additional explanatory notes. Evidence may be basic in parts, for example making general statements about the characteristics described in geometric tolerancing without fully exploring their use and applications. Symbols and codes will be fully expanded upon and explained in plain language using the correct technical terms . (M1)

For Pass standard, the evidence will show learners have identified and correctly interpreted six examples of conventional tolerances, six examples of geometric tolerances and four examples of limits and fits from a range of engineering drawings.

There may be some omissions, for example there may be some lack of clarity in the definitions of terms such as straightness and flatness. (P1)

Learning outcome 2: Understand the use and calibration of measuring devices

For Distinction standard, learners will produce a written justification for the selection of measuring devices in two contrasting applications. They should include relevant characteristics such as portability, precision, ease of use and suitability for the type of measurement being made in their justification and include reasons why at least one possible alternative was not chosen. The evidence will be easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and will use correct technical engineering terms. (D2)

For Merit standard, learners will provide a detailed and illustrated comparison of two measuring devices of a similar type that measure similar characteristics e.g. a Vernier height gauge and a micrometer (similar because they both measure linear dimensions). Annotated diagrams or photographs will be used to support a written comparison which will use accurate engineering terminology, for example there will be clear and correct naming, labelling and annotation of their parts.

Overall, the evidence will be logically structured and provide good coverage of the differences in characteristics, use, calibration and applications suited to each device. (M2)

For Pass standard, learners will explain the characteristics and use of measuring devices in engineering using applied examples. Learners will provide labelled diagrams or photographs with some annotation to support written explanations of the required measuring devices which must include: **three** linear, **two** angular, **one** alignment, **two** comparators, **three** gauges and **one** surface roughness tester along with 2 examples of related ancillary equipment. (P3)

Learners will also explain in detail the calibration of a given measuring device, using two examples from the content. This should make reference to the procedure used for calibration, the standard with which the measuring device is compared, equipment marking and record keeping (P4).

The causes of error when using measuring devices should also be explained with examples of the possible consequences of error. A general treatment of the causes of error encountered when using measuring equipment and how these can be avoided is acceptable for the Pass standard. (P5).

Explanations may have some omissions, for example there may be some lack of clarity in the definitions of technical terms or in the naming and labelling of the parts of measuring devices.

The coverage requirements must be met but evidence may be basic in parts. For example, explaining the characteristics and use of a Vernier calliper without going on to fully cover calibration or applications.

Learning outcome 3: Understand how to plan and carry out quality control procedures

For Distinction standard, learners will produce a written justification that is easy to read and understand by a third party, who may or may not be an engineer. It will be logically structured and will use correct technical engineering terms with a high standard of written language, i.e. consistent use of correct grammar and spelling. (D3)

Each decision taken in the development of the inspection plan for a given scenario will be discussed and justified, e.g. evidence might show that a measuring instrument was chosen to match the precision required, but also because it was easy to read and was able to access the feature being measured easily. Some justifications will include clear reasoning why possible alternatives were not chosen.

For Merit standard, learners will provide a comprehensive inspection plan for a given scenario that will require at least five separate measurements of critical parameters to be taken on a single component or assembly. learners will provide an explanation of each element of an inspection plan as laid out in the unit content (M3)

The plan will be comprehensive and so cover all the elements of an inspection plan as laid out in the unit content. Overall, the evidence will be logically structured and the plan will be both feasible and effective.

For Pass standard, learners will provide a clear inspection plan for a given scenario that will require at least five separate measurements of critical parameters to be taken on a single component or assembly

Examples should be used to help illustrate different elements of the inspection plan.

Overall, the evidence will be logically structured and provide a good overview of how to develop an inspection plan but is likely to contain some technical inaccuracies or omissions. (P6)

Unit 18: Engineering Design

Level: 3

Unit type: Optional

Guided learning hours: 60

Unit introduction

An understanding of how the design process operates within an engineering business is important for anyone considering a career in the design and manufacture of products. This unit provides learners with the opportunity to consider design in a holistic way. It combines study of the technical aspects of engineering design with wider issues such as the environment, sustainability and legislation.

The unit introduces and develops the concept of design for manufacture. It is crucial that the design process be effective. Success in the marketplace can be achieved only if products are fit for purpose, marketable and meet customer requirements. The importance of market research, generation of new ideas and the consequences of poor design are investigated.

Learners will also investigate the issues which influence whether a design proposal should be developed into a final solution suitable for manufacture. These issues include the impact of legislation and standards, the need to conform to environmental and sustainability requirements, materials selection and the types of manufacturing process available. On completion of the unit learners will understand the wider implications of engineering design and the reasons why it cannot be carried out in isolation from the rest of the manufacturing/production process.

The unit content is linked together through a practical task which starts with learners interpreting the requirements of a customer and producing a product design specification (PDS). This is followed by an investigation into the legislation, standards and reference sources that are used by designers who work in manufacturing engineering. This knowledge is then used to influence the production of their own design proposals. These proposals are refined and developed into a final design solution which meets the requirements of the customer. Design ideas will have been communicated using a number of techniques including sketching and formal engineering drawing, design calculations and written commentary.

Learning outcomes

In this unit you will:

1 Know how the design process operates when dealing with customers

2 Know the impact of legislation, standards and environmental and manufacturing constraints can have on the design function

3 Be able to prepare design proposals that meet the requirements of a product design specification

4 Be able to produce and present a final design solution

Content

What needs to be learned
Learning outcome 1: Know how the design process operates when dealing with customers
• The design process: ○ triggers e.g. market pull, demand, profitability, technology push, innovation, market research ○ process of design for manufacture: decision making; use of new technologies e.g. computer aided design (CAD), simulation, rapid prototyping, computer integrated manufacture (CIM); lines of communication. • Customer: ○ customer/client relationship ○ types of customer e.g. external, internal ○ requirements of customer e.g. performance specifications (physical dimensions, mass), compliance to operating standards, reliability and product support, end-of-life disposal, production quantities (custom built, modification to an existing product, small batch, large volume). • Product design specification (PDS): analysis of customer requirements; production of an agreed PDS; documentation e.g. physical dimensions, materials, mass, operation and performance.

What needs to be learned
Learning outcome 2: Know the impact of legislation, standards and environmental and manufacturing constraints can have on the design function

• Legislation and standards: relevant and current legislation, standards and codes of practice e.g. British Standards (BS), International Standards (ISO), electromagnetic compatibility (EMC) directive, European legislation, (European Conformity (CE marking))
• Environmental and sustainable constraints:
  o energy efficiency; environmental impact
  o constraints e.g. Environmental Protection Act, Waste Electronic and Electrical Equipment Directive; end-of-life disposal e.g. refurbishment, recycling, disassembly, material recovery, non-recyclable components.
• Manufacturing constraints:
  o availability of resources e.g. labour, material, equipment
  o influence of physical and mechanical properties of a material in relation to manufacturing methods
  o cost-effective manufacture e.g. set-up cost (jigs, tools), production quantities.
• Health and safety in the workplace e.g. Health and Safety at Work Act, Control of Substances Hazardous to Health (COSHH) Regulations.

Learning outcome 3: Be able to prepare design proposals that meet the requirements of a product design specification
• Requirements of a product design specification (PDS): interpretation of technical requirements e.g. operating performance, physical dimensions; interpret economic requirements e.g. production quantities, product life, market place positioning. • Prepare design proposals: ideas generation e.g. research into existing products, freehand sketching, simulation, flow charts; realistic design proposals e.g. fitness for purpose, manufacturability, aesthetics, ergonomics. • Design reference material: manufacturers' catalogues e.g. screw fixings, bearings, seals, electrical connectors, drive belts, gear drives; materials databases e.g. mechanical properties, physical properties; design databases e.g. structural beam sections, corrosion protection, anthropometric data.

What needs to be learned
Learning outcome 4: Be able to produce and present a final design solution

• Final design solution:
  ○ evaluation of proposals and selection of most appropriate for further development e.g. suitability for available manufacturing processes, cost effectiveness, contribution to profits, visual appearance
  ○ development of design proposal into a feasible solution suitable for prototype manufacture e.g. specify materials, appropriate manufacturing processes, estimation of manufacturing cost, quality
  ○ conformity to relevant legislation and design standards.
• Presentation techniques:
  ○ 2D engineering drawings e.g. general arrangement drawing, assembly drawing, detail drawings, circuit diagrams, flow diagrams, schematic diagrams; drawing conventions and relevant British Standards e.g. BS308, BS8888, BS7307, BS3939, BS2197
  ○ documentation e.g. design diary, logbook, product specification.
• Design calculations e.g. sizes of materials to meet strength requirements, electric motor power, electronic circuit performance, battery life.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Know how the design process operates when dealing with customers		
P1 describe the operation of the design process in an engineering company	M1 assess the possible impact of a poor customer design process on customer relationships and requirements	
P2 interpret the requirements of a given customer and produce a product design specification		
Learning outcome 2: Know the impact of legislation, standards and environmental and manufacturing constraints can have on the design function		
P3 describe the appropriate legislation and standards which apply to the design of two different products		D1 evaluate the impact of legislation and standards on the design process in relation to the profitability of the business
P4 describe the environmental, sustainability and manufacturing constraints which influence the design of a given product		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Be able to prepare design proposals that meet the requirements of a product design specification		
P5 produce design proposals which meet the requirements of a given PDS	M2 analyse the issues which influence whether a design proposal should be developed into a final solution suitable for manufacture.	
P6 extract reference information from component manufacturers' catalogues and materials and design databases	M3 assess the importance of using a range of accurate design reference materials when developing design proposals	
Learning outcome 4: Be able to produce and present a final design solution		
P7 use a range of techniques to present a final design solution which meets the requirements of a given PDS and relevant legislation and design standards.		D2 evaluate a final design solution against customer requirements and a PDS, and suggest improvements.

Essential information for tutors and assessors

Resources

The special resources needed for this unit are access to:

- a range of customer design requirements
- a range of products to investigate design requirement features
- manual drawing equipment
- 2D commercial CAD software
- extracts and illustrations from appropriate drawing standards and conventions
- access to reference material which provides information about the physical and mechanical properties of materials
- access to legislation and design standards
- component and material suppliers' catalogues.

Assessment

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

This unit is assessed internally by the centre and externally verified by Pearson.

The table below shows the recommended approach to assessment detailing suitable forms of evidence for each learning outcome. Centres can use these forms of evidence or other suitable ones. Centres need to provide learners with an appropriate assignment brief to complement the recommended assessment approach.

<table>
<tr><th>Learning outcome</th><th>Recommended assessment approach</th></tr>
<tr><td>1 Know how the design process operates when dealing with customers</td><td>A written report about the design process and its impact on customer relationships. In addition a PDS should be generated from a given customer specification.</td></tr>
<tr><td>2 Know the impact of legislation, standards and environmental and manufacturing constraints can have on the design function</td><td>A written report outlining legislation and standards that apply to two different products and an evaluation of the manufacturing, environmental and sustainability constraints for one of them in terms of profitability for the business.</td></tr>
<tr><td>3 Be able to prepare design proposals that meet the requirements of a product design specification</td><td rowspan="2">A portfolio of design solutions and a written report explaining how a final design solution has been selected. In addition explanations of the importance of accurate design reference materials and an evaluation of the chosen design solution with reference to the given PDS.</td></tr>
<tr><td>4 Be able to produce and present a final design solution</td></tr>
</table>

Learning outcome 1: Know how the design process operates when dealing with customers

For Merit standard, learners will need to assess the impact of a poor design process. To achieve M1 the manufacturer/client relationship should be explored in some depth with evidence supported by examples taken from case studies based on real products. For example, learners could consider the difficulties that could arise if the PDS lacks detail and the engineering company cannot clarify specific requirements with the client. These could be discussed during the visit in the first assignment. M1 builds on knowledge used to achieve P1 and P2 and may be best attempted in the first assignment

To achieve M2 learners should support their reasons for having accurate reference material by using examples taken from documented sources of products which are mission critical (for example correct specification of dimensions and material for a load bearing structure such as a roof beam). As such, a further written task could be set in assignment three to facilitate M2.

For Pass standard, learners give a clear account of how the design process operates in an engineering company and its links to other aspects of the business. (P1)

It is suggested that during the first assignment the evidence for P1 could be gained by learners visiting the design department of an engineering company, carrying out an interview with an engineering designer and preparing a short report. It is important that learners understand that design cannot be carried out in isolation and that it is an income-generating function with the customer having the final say.

After the visit or similar activity, a written task for P2 should be given that asks learners to produce a PDS from the requirements of a given customer. The PDS that learners produce will be appropriate to the customer requirements.

Learning outcome 2: Know the impact of legislation, standards and environmental and manufacturing constraints can have on the design function

For Distinction standard learners should be able to focus on specific legislation and standards when working towards D1. Learners should support their evaluation of the impact of legislation and standards on the design process with examples drawn from documented sources (for example businesses that have either lost market share by being caught out by changes in legislation or others that have benefited through anticipating changes and beating competitors in the market). As such, a task targeting D1 could be set as part of assignment 2. Learners will draw their information together to draw a detailed and valid conclusion on the impact of legislation and standards on the design process in relation to the profitability of the business (D1).

For Pass standard, the tutor gives two different products to each learner and they carry out research in order to describe the legislation and standards that apply to each product (P3) and the environmental, sustainability and manufacturing constraints that influenced the design of one of these products (P4).

Learning outcome 3: Be able to prepare design proposals that meet the requirements of a product design specification

and

Learning outcome 4: Be able to produce and present a final design solution

For Distinction standard, to achieve the criterion D2, learners' evaluations could relate to a design solution provided by the tutor but it may be better to link with P7 so that learners evaluate their own work. A written task in assignment 3 may be appropriate for this. Learners will consider all customer requirements and whether these are met in the final design solution, reaching a detailed and valid conclusion and making relevant suggestions for improvements.

For Merit standard, M2 builds on P5 and P7. Learners analyse relevant issues in detail, including economic issues, manufacturing in quantity and the pressure on a designer to design to a price in order to be competitive. Learners support their work with examples relating to real products that they are familiar with. (M3)

To achieve M3, it is expected that learners will support their assessment of the importance of having a range of accurate reference materials when developing design proposals by using examples taken from documented sources, such as the correct specification of dimensions and material for a load bearing structure such as a I-beam. As such, a further written task could be set to facilitate M3.

For Pass standard, learners will need to demonstrate a basic mastery of design and drawing skills and they produce sketches and drawings which are broadly in line with British Standards and which use simple drawing conventions. Learners' design proposals should meet the requirements of a given PDS (P5). There should be evidence of learners extracting reference information from catalogues, materials and design databases, including details of the sources used. (P6) Learners will use appropriate presentation techniques using drawing conventions and relevant British standards (P7). There should be some evidence of design calculations when presenting evidence for P5, P6 and P7.

For assessment of these criteria a third assignment could be set where a PDS should be given and learners asked to produce a range of design proposals (P5). Three proposals would generally be sufficient although, if the solutions are complex, two would be enough. In doing this, it is important that learners use design reference material (P6) and a range of techniques to present the final solution (P7). The techniques used are dependent on the solution (for example if it involves an electronic system then circuit diagrams will be needed as well as perhaps general arrangement drawings).

Learners will demonstrate a basic understanding of the use of information sources such as books, technical reports, data sheets, catalogues, CD ROM and online databases. They should be selecting, interpreting and applying data extracted from a limited range of sources and will have been given guidance on what to look for.

Design work must show good evidence of knowledge gained from the linked units so that learners can be critical about their evolving designs and adapt them, rather than pursue a single idea. Grading criteria P5 and P6 link the extraction of reference information about materials and components to the design proposals being put forward by the learner. This will give more focus when gathering resource material. It is intended that the assessment evidence for criterion P6 is based on development ideas generated in P5.

14 Suggested teaching resources

This section lists resource materials that can be used to support the delivery of the units across the qualification.

Textbooks

Ambrosius L – *AutoCAD 2009 and AutoCAD LT 2009: All-in-one Desk Reference for Dummies* (John Wiley and Sons, 2008) ISBN 9780470243787

Bird J – *Engineering Mathematics* (Routledge, 2014) ISBN 9780415662802

Boyce A, Cooke E, Jones R and Weatherill B – *Level 3 BTEC National Engineering Student Book* (Pearson, 2010) ISBN 9781846907241

Boyce A, Cooke E, Jones R and Weatherill B – *Level 3 BTEC National Engineering Teaching Resource Pack* (Pearson, 2010) ISBN 9781846907265

Bray S – *Grinding, Honing and Polishing* (Special Interest Model Books, 2009) ISBN 978-1854862525

Cheng R – *Using Pro/Desktop 8* (Delmar, 2004) ISBN 9781401860240

Conforti F – *Inside Microstation* (Delmar, 2005) ISBN 9781418020842

Darbyshire A – *Mechanical Engineering BTEC National Level 3 Engineering Specialist* Units (Routledge, 2010) ISBN 9780080965772

Dieter G, Schmidt L – *Engineering Design* (McGraw-Hill, 2012) ISBN 9780073398143

Evans K – *Programming of CNC Machines* (Industrial Press, 2007) ISBN 9780831133160

Fuller A, Greer A, Taylor G W – *BTEC National Mathematics for Technicians* (Nelson Thornes, 2004) ISBN 9780748779499

Health and Safety Executive – *Essentials of Health and Safety at Work* (HSE Books, 2006) ISBN 9780717661794

Health and Safety Executive – *Management of Health and Safety at Work* (HSE Books, 2000) ISBN 9780717624881

Health and Safety Executive – *Health and Safety in Engineering Workshops* (HSE Books, 2004) ISBN 9780717617173

Higgins R – *Materials for Engineers and Technicians* (Routledge, 2014) ISBN 9781138778757

Hutchinson S – *Performance Management: Theory and Practice* (CIPD, 2013) ISBN 9781843983057

Mullins L J – *Management and Organisational Behaviour*, 10th Edition (FT Publishing International, 2013) ISBN 9780273792642

Simmons C, Maguire D and Phelps N – *Manual of Engineering Drawing* (Butterworth-Heinemann, 2009) ISBN 9780750689854

Smid P – *CNC Programming Handbook* (Industrial Press, 2008) ISBN 9780831133474

Timings R L – *Engineering Materials, Volume 1* (Longman, 1998) ISBN 9780582319288

Timings R L – *Engineering Materials, Volume 2* (Longman, 2000) ISBN 9780582404663

Timings R L – *Basic Manufacturing* (Routledge, 2004) ISBN 9780750659901

Tindell H –*Engineering Materials, Crowood Metalworking Guides* (The Crowood Press, 2014) ISBN 9781847976796

Tooley M and Dingle L – *BTEC National Engineering* (Routledge, 2010) ISBN 9780123822024

Waldock B – *Being Agile in Business: Discover Faster, Smarter, Leaner Ways to Work* (Pearson Education, 2015) ISBN 9781292083704

Yarwood A – *Introduction to AutoCAD 2012* (Routledge, 2011) ISBN 9780080969473

Journals

Business Review Magazine (Phillip Allan Publishers – see www.phillipallan.co.uk)

The Economist (The Economist Newspaper Group Inc)

Websites

http://www.freecadweb.org/	Website for free CAD software resources (FreeCAD).
www.freestudy.co.uk	Engineering Council – open learning tutorials.
www.hse.gov.uk	HSE
https://www.stem.org.uk/	STEM Learning
www.bbc.co.uk/business	BBC News
www.nln.ac.uk	National Learning Network

15 Further information and useful publications

To get in touch with us visit our 'Contact us' pages:

- 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

Key publications:

- *Access arrangements and reasonable adjustments* (Joint Council for Qualifications (JCQ))
- *A guide to recruiting with integrity and enrolling learners onto qualifications* (Pearson)
- *A guide to the special consideration process* (JCQ)
- *BTEC Centre Guide to Managing Quality* (Pearson)
- *BTEC UK Quality Assurance Centre Handbook*
- *Collaborative and consortium arrangements for the delivery of vocational qualifications policy* (Pearson)
- *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy* (Pearson)
- *Equality and diversity policy* (Pearson)
- *Recognition of prior learning policy and process* (Pearson)
- *Supplementary guidance for reasonable adjustment and special consideration in vocational internally assessed units* (Pearson)
- *Suspected malpractice in examinations and assessments - Policies and procedures* (JCQ)
- *UK Information Manual* (Pearson)
- *Use of languages in qualifications policy* (Pearson).

All of these publications are available on our website.

Publications on the quality assurance of BTEC qualifications are also available on our website.

Our publications catalogue lists all the material available to support our qualifications. To access the catalogue and order publications, please visit our website.

Additional resources

If you need further learning and teaching materials to support planning and delivery for your learners, there is a wide range of BTEC resources available.

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

16 Professional development and training

Pearson supports UK and international customers with training related to BTEC qualifications. This support is available through a choice of training options offered on our website.

The support we offer focuses on a range of issues, such as:

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

The national programme of training we offer is on our website. You can request centre-based training through the website or you can contact one of our advisers in the Training from Pearson UK team via Customer Services to discuss your training needs.

BTEC training and support for the lifetime of the qualifications

Training and networks: our training programme ranges from free introductory events through sector-specific opportunities to detailed training on all aspects of delivery, assignments and assessment. We also host some regional network events to allow you to share your experiences, ideas and best practice with other BTEC colleagues in your region.

Regional support: our team of Curriculum Development Managers and Curriculum Support Consultants, based around the country, are responsible for providing advice and support in centres. They can help you with planning and curriculum developments.

To get in touch with our dedicated support teams please visit our website.

Your Pearson support team

Whether you want to talk to a sector specialist, browse online or submit your query for an individual response, there's someone in our Pearson support team to help you whenever – and however – you need:

- Subject Advisors: find out more about our subject advisor team – immediate, reliable support from a fellow subject expert
- Ask the Expert: submit your question online to our Ask the Expert online service and we will make sure your query is handled by a subject specialist.

Please visit our website at qualifications.pearson.com/en/support/contact-us.html

Annexe 1 Glossary of terms used in assessment criteria

This is a summary of the key terms used to define the assessment requirements in the units.

Term	Definition
Analyse	Examine methodically and in detail, typically in order to interpret.
Assess	Considers all the factors/events/concepts that apply to a situation to identify those that are most relevant and arrive at a conclusion.
Compare	Identify the main factors relating to two or more items/situations, explain the similarities and differences, and in some cases say which is best and why.
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 factors or information beyond a simple response
Evaluate	Bring together all information and review it to form a conclusion, drawing on evidence, including strengths, weaknesses, alternative actions, relevant data or information.

Term	Definition
Explain	Provide details and give reasons, examples and/or evidence to support an argument or point. *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.
Interpret	State the meaning, purpose or qualities of something through the use of images, words or other expressions.
Justify	Supports an opinion or proves something is right or reasonable using reasons and/or evidence
Outline	A description setting out the main characteristics or points; write a clear description but without going into too much detail
Review	Making a judgement about a topic or piece of work which relies upon a combination of evidence and some kind of theoretical model(s), construct or practice. A review may lead onto detailed further exploration and/or recommendations for further actions.

TM13/08/19 9781446963159_BTEC_SPLT_L3_MACH_DK_ISS1.DOCX.1-241/0

August 2019

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

Pearson Education Limited. Registered in England and Wales No. 872828
Registered Office: 80 Strand, London WC2R 0RL.

VAT Reg No GB 278 537121