Pearson BTEC Level 2 Diploma in Machining (Foundation Knowledge)

Specification

BTEC Specialist qualification

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Issue 1

Edexcel, BTEC and LCCI qualifications

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

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1 Introducing BTEC Specialist qualifications

What are BTEC Specialist qualifications?

BTEC Specialist qualifications are work-related qualifications available from Entry 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 2 Diploma in Machining (Foundation Knowledge)
Qualification Number (QN)	603/4863/X
Regulation start date	01/08/2019
Operational start date	01/09/2019
Approved age ranges	16–18 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)	586 hours.
Guided learning hours (GLH)	420.
Assessment	Internal assessment.
Grading information	The qualification and units are at a Pass grade.
Entry requirements	No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification. However, centres must also follow the information in our document *A guide to recruiting learners onto Pearson qualifications* (see *Section 6 Access and recruitment*).
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 2 Diploma in Machining (Foundation Knowledge) is for learners who are working, or who are intending to work, as an Engineering Technician in a machinist job role. The qualification is designed to support the off-the-job training and development of apprentices on an Engineering Technician apprenticeship programme (Machinist – Advanced Manufacturing Engineering Pathway). It is also for those individuals who are not on an apprenticeship programme but who wish to achieve a qualification to prepare for employment.

The qualification gives learners the opportunity to:

- develop the technical knowledge and understanding that underpins competence in machining
- learn about a range of transferable skills and professional attributes that support successful performance in the workplace
- achieve a nationally-recognised Level 2 qualification
- develop confidence and readiness for the apprenticeship end-point assessment.

Apprenticeships

The Level 2 Diploma in Machining (Foundation Knowledge) and the Level 3 Diploma in Machining (Development Knowledge) are mandatory requirements within the Engineering Technician Apprenticeship Standard, Machinist – Advanced Manufacturing Engineering Pathway. Learners must achieve the Level 2 Diploma in Machining (Foundation Knowledge) before progressing to the Level 3 Diploma in Machining (Development Knowledge) and the end-point assessment.

Progression opportunities

Learners who achieve the qualification and who have met all other specified requirements of the Apprenticeship Standard, can progress to achieving the full Apprenticeship certification that confirms competency as a machinist.

Alternatively, learners who have achieved the qualification but who have not completed the full Apprenticeship requirements, could progress to a job role such as engineering operative with further training or to other qualifications such as the Level 2 Diploma in Engineering Operations.

Industry support and recognition

The Pearson BTEC Level 2 Diploma in Machining (Foundation Knowledge) was developed through close collaboration with the Engineering Technician Trailblazer Group, Semta (the Sector Skills Council for Science, Engineering and Manufacturing Technologies), 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 2 Diploma in Machining (Foundation Knowledge)

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

Minimum number of units that must be achieved	7
Number of mandatory units that must be achieved	5
Number of optional units that must be achieved	2

Unit number	Mandatory units	Level	Guided learning hours
1	Machining in an Engineering Environment	2	60
2	Engineering Techniques	2	60
3	Fitting and Assembly Techniques	2	60
4	Business Improvement Techniques	2	50
5	Engineering Mathematics and Science Principles	2	90
6	Principles of Turning and Milling **(barred combination with Units 7 and 8)**	2	80
7	Manual Turning Techniques **(barred combination with Unit 6)**	2	50
8	Manual Milling Techniques **(barred combination with Unit 6)**	2	50
9	Principles of Computer Numerical Control (CNC) Turning and Milling **(barred combination with Units 10 and 11)**	2	80
10	Computer Numerical Control (CNC) Turning Techniques **(barred combination with Unit 9)**	2	50

Unit number	Mandatory units	Level	Guided learning hours
11	Computer Numerical Control (CNC) Milling Techniques **(barred combination with Unit 9)**	2	50
12	Computer Aided Design	2	90
13	Grinding Techniques	2	50

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(s) 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

No prior knowledge, understanding, skills or qualifications are required for learners to register for this qualification.

Access to qualifications for learners with disabilities or specific needs

Equality and fairness are central to our work. Pearson's *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 Apprenticeship Standards please refer to the document *Apprenticeship funding: rules and guidance for employers* 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 knowledge 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; it should not be split into two or more assignments.
- The assignment must be targeted to the learning outcomes; however, 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.
- 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. 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. 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 *Pearson Guidance for reasonable adjustments and special consideration in vocational internally assessed units*. 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*.

Both documents are on the policy page of our website.

Special consideration

Centres must operate special consideration in line with the guidance given in the Pearson document *Guidance for reasonable adjustments and special consideration in vocational internally assessed units* which is on our website. 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.* This document is on the JCQ website: www.jcq.org.uk

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 Pearson's *Centre Guidance: Dealing with malpractice and maladministration in vocational qualifications*, 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 it 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.

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 M2(a) form (downloadable from www.jcq.org.uk/malpractice) with supporting documentation to pqsmalpractice@pearson.com. Where Pearson receives allegations of malpractice from other sources (for example Pearson staff, anonymous informants), the Investigations team will conduct the investigation directly or may ask the head of centre to assist.

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 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 *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 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.

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 – 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: Machining in an Engineering Environment

Level: 2

Unit type: Mandatory

Guided learning hours: 60

Unit introduction

Machining is the production of components through techniques such as turning and milling. In this unit, you will develop your knowledge of the role of a machinist and the machine tools used.

You will develop mental and practical skills, required for working in an engineering environment, and expertise in the workplace, whether in a small enterprise or in a multinational company with a global influence. However, the engineering workplace, and machining operations in particular, can present hazards that need to be understood and respected so that you and others around you stay safe. You will explore current health and safety legislation and safe working practices related to machining.

You will explore the different types of engineering organisations that complete machining operations and you will also explore how they develop their workforce to ensure that they have the skills they need to remain economically competitive.

Finally, you will explore the tools and equipment required for machining tasks.

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Know the job role of a machinist	1.1	Describe the job role of a machinist
		1.2	Outline typical machine tools
2	Understand the requirements of an engineering organisation in meeting health and safety legislation and regulations	2.1	Describe the principal provisions of the Health and Safety at Work etc. Act 1974 (HASAW)
		2.2	Describe the safe working practices to be followed and what to do in case of an emergency in a machining environment
		2.3	Explain how the 'six pack' regulations contribute to a safe and effective workplace
		2.4	Explain how current legislation affects the health and safety of employers, employees and the public
		2.5	State the mandatory procedures for reporting accidents or injuries in an engineering environment
		2.6	Outline safety precautions when using machine tools
3	Understand the continuous development of skills and working relationships	3.1	Explain the roles and responsibilities of both the employer and employee in the development of skills and working relationships
		3.2	State the benefits of continuous development to both employees and their workplace
		3.3	Describe the types of employee development procedures that are in used in the workplace

Learning outcomes		Assessment criteria	
4	Understand the internal and external environments associated with the operations of an engineering organisation	4.1	Outline different engineering sectors
		4.2	Describe the different types of engineering organisations in the United Kingdom
		4.3	Describe the different organisational structures found in the engineering industry
		4.4	Describe the departmental functions in an engineering organisation
		4.5	Describe how machining relates to design, manufacturing and quality control functions
		4.6	Describe the different categories of employee in the engineering industry
		4.7	Explain the factors that influence change in the engineering industry
		4.8	Explain the effects of industrial change on the requirements of the workforce
5	Understand the requirements of engineering machining operations	5.1	Describe the tools and methods employed in machining an engineered component
		5.2	Describe the safe use of work holding equipment for machining operations
		5.3	Describe the purpose of standards and the requirements applied to machining operations
		5.4	Describe how machined features are shown in engineering drawings

Unit content

What needs to be learned
Learning outcome 1: Know the role of a machinist
1A Role of machinist • Role of machinist – uses machine tools to create components from specialist materials; to set up, operate and adjust/edit equipment settings of machine tools being used; to produce, prove, edit programs for CNC machines; to measure and check components being produced to ensure components meet specification. **1B Machine tools** • Machine tools – centre lathe, vertical and horizontal milling machines, horizontal and cylindrical grinding machines, electro discharge machines, single and multi-axis CNC machine tool centres; conventional machines; CNC machines.
Learning outcome 2: Understand the requirements of an engineering organisation in meeting current health and safety legislation and regulations
2A Principal provisions of legislation and regulations that apply to engineering environments All legislation cited in the content is current at the time of publication. The most recent legislation must be taught and assessed. • The purpose of the Health and Safety at Work etc. Act 1974 (HASAWA). • The purpose and content of the Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended). • The purpose and content of the Health and Safety (Safety Signs and Signals) Regulations 1996. • The purpose and content of the 'six pack' Regulations: o Management of Health and Safety at Work Regulations 1999 o Manual Handling Operations Regulations 1992, amended 2002 o Display Screen Equipment Regulations 1992 o Workplace (Health, Safety and Welfare) Regulations 1992 o Provision and Use of Work Equipment Regulations 1998 o Personal Protective Equipment (PPE) Regulations 2002. • The safe use of tools and equipment, in accordance with the Provision and Use of Work Equipment Regulations (PUWER) 1998.

What needs to be learned

2B Safe working practices associated with the operations within an engineering environment

- Safe working procedures with electricity; procedures to be followed in the event of electric shock (isolation from the electrical supply, isolation of the electrical supply and resuscitation procedures).
- Fire prevention and emergency procedures (role of nominated person, fire action plan, training, fire exits, escape routes, assembly points).
- Factors that influence the choice of Personal Protective Equipment (PPE) for given situations, e.g. noise levels, hazardous materials.

2C Safety procedures when using machine tools

- Following safety procedures when using machine tools – being alert to moving parts; ensuring machine guards in place; using emergency stop; machine isolation; wearing appropriate PPE; keeping work area clean and tidy; removing burrs or sharp edges; safely handling machine tools for drilling, turning and milling; tool breakage procedure; swarf handling and disposal, backlash in machine slides; cutting fluids.

Learning outcome 2: Understand the requirements of an engineering organisation in meeting current health and safety legislation and regulations

2C How current health and safety legislation affects employers, employees and the public

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

2D Mandatory procedures applicable to the reporting of accidents or injuries within an engineering working environment

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

What needs to be learned

Learning outcome 3: Understand the roles and responsibilities of both employers and employees in the continuous development of skills and working relationships

3A Responsibilities of both the employer and employee in the development of skills and working relationships

- Employer: company induction, appraisals, Investors in People (IiP), ongoing feedback.
- Employee: attend training, follow organisational procedures, review own performance, continuous personal development (CPD), mentoring/buddy system.
- Importance of developing and maintaining effective working relationships in the working environment and the results if these relationships break down, including with peers, with subordinates, with management, with outside people/organisations.

3B Roles and responsibilities of both employer and employee in personal development procedures

- Benefits of continuous personal development: keeping skills and knowledge up to date, goal creation, career progression, contributes to effective working.
- Main factors when developing a Personal Development Plan for a given situation; main factors - identifying specific goals, developing plan of action, monitoring performance, evaluating effectiveness.

Learning outcome 4: Understand the internal and external environments associated with the operations of an engineering organisation

4A Engineering sectors

- Aerospace, automotive, communications, electrical/electronic, mechanical.

4B Types of engineering organisations in the United Kingdom

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

4C Types of organisational structures within the engineering industry

- For example, flat, hierarchical, matrix.

4D Departmental functions within an engineering organisation

- Research and development, design, purchasing, production/manufacturing, quality control, sales, marketing, customer service, human resources.
- Role of machining in relation to design, manufacturing and quality control functions.

What needs to be learned

4E Categories of employees within the engineering industry

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

4F Factors that influence change within the engineering industry

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

4G Effects of industrial change on the requirements of the workforce

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

Learning outcome 5: Understand the requirements of engineering machining operations

5A Tools and methods employed in machining operations

- Tools and their uses in machining operations, e.g. bench/pillar drills, lathes, milling machines, cutting tools, bits.
- Types of measuring equipment used during machining operations to ensure compliance with specifications, e.g. tape measure, micrometre, vernier callipers.
- Typical procedures that are commonly used during machining operations, including: marking out, drilling, reaming, turning, facing, parting off, shaping, boring, cutting screw threads.

5B Safe use of work holding equipment

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

What needs to be learned
5C Purpose of the tools used in machining operations • Using appropriate tools and equipment to produce an assembly to given specification. • Types of cutting tool materials and their properties, e.g. high-speed steels (HSS), tungsten carbide, diamond, cubic boron nitride. • Typical cutting tools, including twist drills, machine and hand reamers, counter bores and counter sinks, facing tools, parting-off tools, boring bars, milling cutters, etc. • Use of cutting fluids.
Learning outcome 5: Understand the requirements of engineering machining operations
5D Standards and requirements applied to fitting and assembly • Role and purpose of The British Standards Institute (BSI) and The International Organization for Standardization (ISO). • Typical features found on fitting/assembly drawings, e.g. tolerance, limits of size, nominal size, thread size, surface finish.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need access to:

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

Assessment

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

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

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

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

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners complete an information sheet for new apprentices that covers the role of an engineering machinist and the types of machine tools they use in their organisation. Learners who are not in employment can base their evidence on an organisation with which they are familiar. Learners **will**:

1. give a clear account of the role of a machinist, including the types of components they produce and their responsibilities to quality assurance.
   They will relate their account to their own workplace or an organisation with which they are familiar (AC1.1)
2. give an overview of the machine tools used by machinists in their organisation.
   They will include the type of machine, its purpose, how it is used to produce components and the type of components it produces (AC1.2).

Learning outcome 2

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

1. describe the principal provisions of the Health and Safety at Work etc. Act (1974) in relation to the engineering workplace. Learners must include details of how the provisions protect those in the engineering workplace (AC2.1)
2. describe the procedures to be followed in the event of an electric shock and in the case of a fire in the engineering workplace. Learners must provide clear details of the actions that must be taken in both instances (AC2.2)
3. explain how each of the 'six pack' regulations contributes to a safe and effective workplace. For each of the regulations, learners must give one detailed example of their use within an engineering context (AC2.3)
4. explain the main requirements of at least three different pieces of health and safety legislation. For each piece of legislation, learners must include **one** detailed example of how each piece of legislation affects each of:
   - employers
   - employees
   - the public

   in relation to the engineering workplace (AC 2.4)
1. state the procedures to be followed in the engineering workplace when reporting accidents and incidents (AC2.5)
2. give an overview of the safety procedures to follow when using the machine tools in their workplace, including the use of machine guards, correct PPE, tidying work area and safe operation of machines (AC2.6).

Learning outcome 3

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

1. explain **two** responsibilities of the employer and **two** responsibilities of the employee in the development of an effective workplace. For each responsibility, learners must include **one** detailed reason for how they contribute to an effective workplace (AC3.1)

2. state **two** benefits to employees and **two** benefits to their workplace of continuous personal development (AC3.2)
3. describe the types of employee development procedures that are in use in the workplace. For example, learners could describe their apprenticeship induction to the company, including how they are supported, on a daily basis, in the workplace (AC3.3).

Learning outcome 4

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

1. give an overview of the engineering sectors that **two** different types of engineering organisation, such as a multinational and an SME, belong to, including the main characteristics of each. (4.1)
2. describe the two organisations including details of
    - the types of each organisation (AC4.2)
    - the departmental functions in the **two** organisations, including details of the purpose of each departmental function. Learners correctly identify the departmental function where machining sits in each organisation (AC 4.4)
    - the categories of employees in each organisation (AC4.6)
    - the structures of each organisation (AC4.3)
1. give an overview of how machining operations relate to other functions in the organisation (4.5)
2. explain how **two** factors could influence change in the engineering industry with **one** valid example for **each** factor (AC4.7)
3. explain **two** effects of industrial change on the requirements of the workforce with **one** valid reason for **each** (AC4.8).

Learning outcome 5

To satisfy the assessment criteria for this learning outcome, learners will refer to a practical task they have undertaken and complete a logbook demonstrating the use of typical tools and procedures employed in machining operations. Learners **will**:

1. use photographic and written evidence to describe the tools, measuring equipment and procedures used during the practical activity (AC5.1)
2. describe the safe use of drilling machines, lathes and/or milling machines (AC 5.2)
3. describe the purpose of the machine tools required to complete the machining exercises (AC5.3)

4. describe the purpose of engineering standards used in their own engineering organisation. Learners must name standards used and outline the areas they cover (AC5.4)
5. describe **three** machining features that can be found in engineering drawings. Learners present this evidence through annotating a drawing provided by the tutor (AC5.5).

Unit 2: Engineering Techniques

Level: 2

Unit type: Mandatory

Guided learning hours: 60

Unit introduction

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

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

Learning outcomes and assessment criteria

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

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

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

Unit content

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

What needs to be learned

Learning outcome 4: Understand measurement and marking out techniques

4A Measurement and marking out techniques

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

Essential information for tutors and assessors

Essential resources

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

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

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

Assessment

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

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

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

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

Learning outcome 1

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

1. describe the **four** communication methods that can be used to communicate engineering information. For each method, learners must give **one** suitable example from the engineering workplace of when it would be used (AC1.1)

2. describe the advantages and disadvantages of using each form of communication to communicate **two** given forms of engineering information. **One** form should include engineering drawings using a standard drawing convention and symbols (AC1.2, 1.3)
3. explain the effects of communicating engineering information outside of national boundaries and the problems that can arise due to misinterpretation. Learners are to research and give **two** examples of engineering failures due to misinterpretation of information where parts are manufactured globally (AC1.4).

Learning outcome 2

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

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

Learning outcomes 3 and 4

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

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

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

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

Unit 3: Fitting and Assembly Techniques

Level: 2

Unit type: Mandatory

Guided learning hours: 60

Unit introduction

Engineers use a large variety of machinery to produce components that can be assembled into finished products. However, ensuring these components come together to form a quality product is a job for skilled fitters and assemblers.

In this unit, you will learn about the range of hand and measuring tools available to engineers during assembly and fitting operations and how to use them safely. You will also explore the types of cutting tools and work holding devices that can be used before investigating the need for engineering standards; and how fitting and assembly details can be determined from engineering drawings by using standard conventions and symbols.

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the hand tools and methods employed in fitting and assembly operations	1.1	Describe the range of hand tools and their uses in fitting and assembly operations
		1.2	Describe the specific safety precautions to take when using fitting and assembly hand tools
		1.3	Describe the range of measuring equipment used in fitting and assembly operations
2	Understand the safe use of work holding equipment used in fitting and assembly operations	2.1	Describe the range of work holding devices that can be used in fitting and assembly operations
		2.2	Describe the safe use of work holding equipment
		2.3	Describe the procedure for mounting and aligning work holding devices
3	Understand the principles of cutting tools used in fitting and assembly operations	3.1	Describe the range of cutting tools used in fitting and assembly operations
		3.2	Explain the reasons for cutting tools having rake and clearance angles
		3.3	Define the meaning of the term cutting speed
		3.4	Describe the factors that affect cutting speed
		3.5	Describe how the correct spindle speed and cutting speed is determined
4	Understand the requirements of engineering fitting and assembly operations	4.1	Describe the purpose of standards and requirements applied to fitting and assembly in an engineering organisation
		4.2	Define the meaning of engineering terms used in fitting and assembly
		4.3	Describe how fitting and assembly features are shown in engineering drawings

Unit content

What needs to be learned
Learning outcome 1: Understand the hand tools and methods employed in fitting and assembly operations

1A Hand tools used in fitting and assembly operations
• Types of hand tools including:
  ○ hammers and mallets
  ○ chisels
  ○ files and rasps
  ○ pin punches
  ○ screwdrivers
  ○ drills
  ○ drifts
  ○ pliers
  ○ snips
  ○ torque wrenches
  ○ spanners
  ○ socket wrenches
  ○ saws.
1B Safe use of hand tools
• Procedures that must be followed to safely use typical hand tools found in an engineering environment, including:
  ○ selecting the correct tool for the job
  ○ pre-use inspection
  ○ appropriate manual handling techniques (single person or with assistance)
  ○ correct operation of the hand tool, e.g. correct use of a hammer, torque wrench, socket wrenches
  ○ post-use inspection.

What needs to be learned
Learning outcome 1: Understand the hand tools and methods employed in fitting and assembly operations

1C Measuring equipment used in fitting and assembly operations
• Types and use of measuring equipment including:
  ○ callipers
  ○ rules and squares
  ○ dividers
  ○ micrometres
  ○ dial test indicators
  ○ vernier callipers
  ○ bore gauges
  ○ go/no-go gauges.

Learning outcome 2: Understand the safe use of work-holding equipment used in fitting and assembly operations

2A Work-holding devices used in fitting and assembly operations
• Types of work-holding devices including:
  ○ vices
  ○ clamps
  ○ jigs
  ○ fixtures
  ○ collets
  ○ chucks
  ○ sleeves
  ○ angle plates
  ○ mandrels.
2B Safe use of work-holding equipment
• Procedures that must be followed to safely use typical work-holding equipment found in an engineering environment, including:
  ○ selecting the correct device for the job
  ○ pre-use inspection
  ○ appropriate manual handling techniques (single person or with assistance)

What needs to be learned

- correct operation of the work-holding device, e.g. correct assembly of a vice to a pillar drill
- post-use inspection
- typical methods used to prevent damage to the workpiece while using work-holding equipment.

Learning outcome 3: Understand the principles of cutting tools used in fitting and assembly operations

3A Cutting tools used in fitting and assembly operations

- Types of cutting tools, including:
  - hacksaws
  - twist drills
  - reamers
  - counterbores
  - countersinks
  - hole saws and tank cutters
  - thread taps and dies
  - files and rasps.

3B Cutting tool terminology

- Reasons for cutting tool rake and clearance angles and how they affect cutting efficiency
  - rake and clearance angles of twist drills
  - the effect of the material being cut on the rake angle
  - the meaning of the term cutting speed
  - the factors affecting correct cutting speed selection
  - the use of charts to determine suitable spindle speeds
  - calculation of correct spindle speeds from given cutting speeds using:

$$s = \frac{\pi dn}{1000}$$

What needs to be learned

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

4A Engineering standards

- The role of the British Standards Institution (BSI) and the International Organization for Standardization (ISO).
- The types of standard including:
  - dimensional standards
  - performance and quality standards
  - standard methods of test
  - standard technical terms including:
    - limits of size
    - tolerances
    - clearance fit
    - transition fit
    - interference fit
  - standard codes of practice
- Engineering drawing conventions and symbols including:
  - 3rd angle orthographic projection
  - drawing symbols and features:
    - threaded holes
    - counterbore
    - countersink
    - fillet.
  - line types:
    - centrelines
    - hidden detail lines
    - hatching
  - surface finish

What needs to be learned
○ dimensions: ▪ pitch circle diameter (PCD) ▪ radius ▪ diameter ▪ dimension lines ▪ scale. ○ material requirements ○ parts list

Essential information for tutors and assessors

Essential resources

There are no special resources needed for this unit but learners would benefit from being shown and familiarising themselves with typical tools used in fitting and assembly operations.

Assessment

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

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

The assessment for this unit should be set in a specific organisational context, draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria.

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

Learning outcomes 1 and 2

To satisfy the assessment criteria for these learning outcomes, learners could produce a presentation to share with new apprentices that details the range of hand tools, measuring tools and work-holding devices used during fitting and assembly operations. Learners **will**:

1. describe the operation of **five** types of hand tools and their safe usage including pre- and post-use inspections, giving suitable examples from their own workplace (1.1, 1.2)
2. describe the operation of **five** types of measuring equipment, giving suitable examples from their own workplace (1.3)
3. describe the operation of **five** types of work-holding device and their safe usage, including details of the correct procedures for mounting and aligning, giving suitable examples from their workplace (2.1, 2.2, 2.3).

Learning outcome 3

To satisfy the assessment criteria for this learning outcome, learners could produce a written report to share with their line manager that details the range of cutting tools and associated principles of operation. Learners **will**:

1. describe **five** types of cutting tool that can be used during fitting and assembly operations, giving suitable examples from their workplace (3.1)
2. explain the reasons why cutting tools have rake and clearance angles and the effect of rake angles on cutting efficiency, and explain the impact that materials being cut have on the rake angle of cutting tools (3.2)
3. define the term 'cutting speed' and provide details of the factors that can affect it (3.3, 3.4)
4. describe how cutting and spindle speeds can be determined for a given cutting operation (3.5).

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners could produce a written report to share with their line manager that details the requirement for engineering standards. Learners **will**:

1. describe the role of the BSI and ISO standards and the key features of **three** types of standards in relation to fitting and assembly (4.1)
2. define the meaning of **two** of the standard technical terms in the unit content (4.2)
3. describe the meaning of **six** engineering drawing conventions and symbols and how they are denoted on engineering drawings (4.3).

Unit 4: Business Improvement Techniques

Level: 2

Unit type: Mandatory

Guided learning hours: 50

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand what is meant by 'workplace organisation'	1.1	Describe the methods of improving and sustaining workplace organisation
		1.2	State the purpose and importance of Standard Operating Procedures (SOPs) in relation to workplace organisation
		1.3	Explain the effects of a disorganised work area on the engineering process
2	Understand the continuous improvement process	2.1	Explain what is meant by continuous improvement in an engineering organisation
		2.2	Describe the benefits of continuous improvement in an engineering organisation
		2.3	Describe how the categories of work found in an engineering organisation relate to continuous improvement
		2.4	Describe the categories of waste found in an engineering environment
		2.5	Explain how waste can be reduced or eliminated in an engineering environment
3	Understand visual management techniques and their influence on continuous improvement	3.1	Describe the types of visual management technique that can be used in an engineering organisation
		3.2	Describe the benefits of visual management on an engineering organisation
4	Understand problem-solving techniques	4.1	Describe the types of problems found in an engineering environment
		4.2	Describe problem-solving techniques used in an engineering environment
		4.3	State the benefits of problem solving in an engineering environment

Unit content

What needs to be learned
Learning outcome 1: Understand what is meant by 'workplace organisation'
1A Methods of improving and sustaining workplace organisation • Use of Standard Operating Procedures (SOPs) to enhance workplace organisation. • Importance of the correct use of storage in the workplace. • Influence of improved floor space utilisation (reduced motion and transportation) on continuous improvement. • Importance of a clean workplace and how the lack of cleaning affects workplace organisation. • Effects that the removal of unused items/equipment has on the working environment, e.g. reduced clutter, improved light levels, improved health and safety. **1B Problems associated with disorganised work environments** • Effects of a disorganised workplace on an engineering organisation, including poor quality, increased costs, reduced efficiency, poor delivery times, poor morale/teamwork, poor health and safety, loss of repeat orders.
Learning outcome 2: Understand the continuous improvement process
2A Continuous improvement process • Definition: the purpose of the continuous improvement process and what it will achieve for an individual business (identifying opportunities for streamlining work and reducing waste), the Plan – Do – Check – Act (PDCA) improvement cycle. **2B Benefits of continuous improvement** • Reduced cost, e.g. production. • Improved quality, e.g. reduced defects. • Improved safety, e.g. safe to use. • Improved working practices, e.g. reduced operator motion. • Improved delivery, e.g. reduced transportation time, reduced lead time. • Reduction of waste, e.g. over processing, excess inventory. • Resource utilisation, e.g. reduced waiting time. • Improved customer satisfaction, e.g. meeting customer requirements. **2C Categories of work and categories of waste** • The three categories of work undertaken in an engineering organisation – value added, non-value added, waste. • The effect that each category of work has on the continuous improvement process.

What needs to be learned
• Different categories of waste, including transport, inventory, motion, waiting, overproduction, over processing, defects, skills/unrecognised people potential. • Reducing/eliminating waste.
Learning outcome 3: Understand visual management techniques and their influence on continuous improvement
3A Types of visual management • The range of visual management tools that can be utilised in an engineering organisation, e.g. shadow boards, PDCA worksheets, colour coding, Kanban (visual boards), other area-specific types of visual management. **3B Benefits of sound visual management** • Greater ownership. • Everyone knows what is going on without needing to ask. • Simplification of stock taking. • Improved safety. • Potential problems are highlighted at an earlier stage.
Learning outcome 4: Understand problem-solving techniques
4A Problems • Types of problem in work environments, e.g. manufacturing errors, premature replacement of cutting tools, lack of raw materials due to late deliveries from suppliers, production time overrun. • Benefits of solving problems in a work environment, e.g. improved productivity, improved customer satisfaction, reduction in non-value-added activity, reduction in waste, improved staff morale. • Consequences of not finding the root causes of problems, e.g. problems will reoccur, 'treating the symptom and not the cause'. **4B Techniques** • Techniques that can be used to identify/solve problems in an engineering organisation, e.g. tally charts, flow charts, histogram/Pareto chart, benchmarking, process mapping, correlation diagram, run diagram, statistical process control, control charts, Gantt charts, root cause paths, value stream maps, Ishikawa diagrams (cause and effect, fishbone), brainstorming, mind mapping, '5 Why' analysis.

Essential information for tutors and assessors

Essential resources

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

Assessment

- This section must be read in conjunction with *Section 8 Assessment*.
- This unit is internally assessed. To pass the unit, the evidence that the learner presents for assessment must demonstrate that they have met the required standard specified in the learning outcomes and assessment criteria.
- The assessment for this unit must be set in a specific engineering workplace to allow learners to apply their knowledge and understanding in a realistic and practical way.
  It must draw on learning from the unit and be designed in a way that enables learners to meet all the assessment criteria. The engineering workplace can be either their own employer or another single engineering organisation with which they are familiar.
- A recommended assessment approach is given below. Centres are free to create their own assessment as long as they are confident that it enables learners to provide suitable and sufficient evidence to meet the stated standard of the assessment criteria and achieve the learning outcomes.

Learning outcomes 1 and 3

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

1. give detailed reasons why a disorganised working environment can affect:
   - health and safety
   - morale/teamwork
   - quality
   - profit
   - efficiency
   - delivery times.

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

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

Learning outcome 2

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

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

Learning outcome 4

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

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

Unit 5: Engineering Mathematics and Science Principles

Level: 2

Unit type: Mandatory

Guided learning hours: 90

Unit introduction

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

Learning outcomes and assessment criteria

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

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

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

Unit content

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

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

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

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

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

1F Calculating areas and volumes
• Using formulae for calculating areas of shapes:
  ○ squares
  ○ triangles
  ○ rectangles
  ○ circles and semicircles
  ○ compound shapes made from squares, triangles, rectangles, circles and/or semicircles.
• Using formulae and appropriate units to calculate volumes of solids:
  ○ triangular prisms
  ○ cubes
  ○ cylinders
  ○ rectangular prisms
  ○ cones
  ○ spheres.

What needs to be learned

- Using appropriate units to calculate volumes of composite solid shapes made from:
  - rectangles
  - triangles
  - circles and/or semicircles.

1G Calculating simple power of numbers

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

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

1H Applying algebraic methods

- Algebraic equations
  - changing the subject of an equation
  - substituting numerical values into algebraic equations
    - solving simple algebraic equations for
    - single variable
    - systems of linear equations.
- Manipulating algebraic expressions:
  - simplifying, changing form of and evaluating algebraic expressions by
    - collecting like terms
    - multiplying a single term over a bracket
    - taking out common factors
    - expanding products of two or more binomials.
- Simple engineering formulae, e.g.:
  - (electrical) $V = IR$, $P = VI$, $P = I^2R$

What needs to be learned
○ (mechanical) $v = u + at$, $s = \frac{1}{2}(u + v)t$, $\sigma = F/A$ • Complex engineering formulae, e.g.: ○ (electrical) $V = V_0 \sin 2\pi ft$, $Xc = \frac{1}{2} \pi fC$, $\frac{1}{2}QV = \frac{1}{2}CV^2$, ○ (mechanical) $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$, $\frac{1}{2}mv^2 = mgh$
Learning outcome 2: Be able to use simple graphs in engineering
2A Graphical methods • Using axes, grid lines, origin, scales. • Working with coordinates in four quadrants. • Identifying constant, linear, quadratic, cubic, trigonometric functions. • Plotting straight line graphs in the coordinate plane (use form y = mx + c). • Finding an equation of line through two given points or one point with given gradient. • Identifying gradients and intercepts of linear functions: ○ graphically ○ algebraically. **2B Extracting data from graphs used in engineering** • Interpreting graphs of linear functions. • Interpreting graphs of quadratic and trigonometric functions. • Non-standard functions to find approximate solutions to: ○ simple kinematic problems ○ speed ○ distance ○ acceleration. • Calculating or estimating: ○ gradients of graphs ○ areas under graphs. • Interpreting results in an engineering context e.g.: ○ distance-time graphs ○ velocity-time graphs.

What needs to be learned

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

3A Atomic structure

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

3B Chemical elements and their positions in the periodic table

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

What needs to be learned

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

3C Chemical compounds and their physical properties

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

3D Classical states of matter

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

Changes in arrangement, movement and energy of particles during inter-conversions.

What needs to be learned

Learning outcome 4: Know the physics of engineering systems

4A Principle of statics

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

What needs to be learned

Learning outcome 4: Know the physics of engineering systems

4B Principles of kinetics

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

Learning outcome 4: Know the physics of engineering systems

4C Principles of dynamic systems

- Basic principles of dynamic systems:
  - units – joule (J) as the unit of energy, watt (W) as the unit of power
  - equations relating power, time and energy transferred or work done
    - $P = E/t$
    - $P = W/t$
    - Calculations related to dynamic systems
  - efficiency = useful energy output/total energy input
  - efficiency = useful power output/total power input.
- Basic principles of thermodynamic systems:
  - energy transfers from one place to another by conduction, convection, radiation.

What needs to be learned

• Properties of simple mechanical systems:
  ○ basic lifting system principles
  ▪ velocity ratio
  ▪ mechanical advantage
  ○ coefficient of friction, static and dynamic friction, use of the formula F = μR.

Learning outcome 5: Know the classification and properties of engineering materials
5A Classification of materials: • Metallic (pure metals, alloys, ferrous, non-ferrous). • Non-metallic materials. • Composites. • Natural materials. • Thermoplastics. • Thermosetting plastics. • Ceramics. • Polymers. • Smart materials. **5B Basic mechanical properties of engineering materials** • Density. • Manufacturability. • Strength (yield, tensile, fracture). • Elastic limit. • Proportional limit. • Ductility. • Toughness of a range of engineering materials, e.g. low carbon/mild steel, high carbon steel, aluminium/aluminium alloy, brass/brass alloy, composites. **5C Typical forms of material supply** • Forms of engineering stock materials, e.g. sheet, plate, bar, wire, section, hot and cold rolled.

What needs to be learned

5D Heat treatment processes for metallic materials

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

Essential information for tutors and assessors

Essential resources

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

Assessment

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

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

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

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

Learning outcome 1

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

Learners **will**:

1. use arithmetical calculations in **two** engineering contexts. Learners must show they can carry out calculations including:
   - adding, subtracting, multiplying, dividing
   - use of whole numbers, decimal numbers, fractions
   - use of positive and negative integers
   - conversion of units
   - basic functions within arithmetical calculations
   - at least **one** calculation related to ratio and/or proportion
   - at least **one** calculation related to percentages
   - at least **one** calculation related to simple powers of numbers
   - applying trigonometry in at least **one** engineering context
   - finding the areas and volumes of **three** simple and **three** compound shapes from given data in an engineering context.

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

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

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

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

Learning outcome 2

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

Learners **will**:

1. use given engineering data to plot a linear graph and establish gradient, intercept and the law connecting the variables in an engineering context. For example, learners could plot a distance-time graph for a car travelling at constant velocity

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

Learning outcomes 3 and 4

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

1. describe the nature of matter, including the meaning of the atomic number and the composition of atoms (AC3.1)

2. define the term 'chemical element', and give a clear account of how elements are arranged on the periodic table. Learners must then outline the basic element structure (AC3.2)

3. define the terms 'molecule' 'compound' and 'mixture' and describe, giving relevant examples, the **three** types of chemical bonding and their physical properties (AC 3.3)

4. describe the arrangement, movement and energy of particles in the **three** classical types of matter and how these change during inter-conversion between states (AC3.4)

5. define the terms 'force', 'couple' and 'moment' and give a clear account of how moments and couples act on **two** simple static systems with reference to engineering calculations using the correct SI units (AC4.1, 4.2)

6. describe the concepts of stress and strain and **one** of the following concepts of elasticity, compression, shear, tension and torsion. Learners must relate their descriptions to **two** engineering contexts using the correct SI units (AC4.3)
7. describe the basic principles of rotational motion. Learners must refer to relevant calculations and formulae (AC4.4)
8. describe the basic principles of periodic motion. Learners must define pendular movement and refer to relevant principles and theories of harmonics and resonance (AC4.5)
9. describe the energy transferred (work done) in a given time for **one** thermodynamic system and **one** mechanical system (AC4.6, 4.7)
10. calculate the amount of friction in **two** simple engineering contexts using dynamics formulae (AC4.7).

Learning outcome 5

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

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

Unit 6: Principles of Turning and Milling

Level: 2

Unit type: Optional

Guided learning hours: 80

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the equipment and procedures used in turning and milling operations	1.1	Describe the health and safety requirements associated with turning and vertical milling operations
		1.2	Describe the safety precautions relating to the setting and use of a centre lathe and vertical milling machine
		1.3	State the personal protective equipment (PPE) that must be worn when carrying out turning and milling operations
		1.4	Describe centre lathe and vertical milling machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in turning and milling operations	2.1	Describe the functions and operation of the component parts and controls of centre lathes
		2.2	Describe the functions and operation of the component parts and controls of typical vertical milling machines
		2.3	Describe the types of operations that can be carried out on a centre lathe and a vertical milling machine
3	Understand the types and applications of cutting tools used in turning and milling operations	3.1	Describe the properties of cutting tool materials used in turning and vertical milling operations
		3.2	Describe cutting tool profiles used in turning and vertical milling operations
		3.3	Describe the function of the rake and clearance of a single point turning tool and a milling cutter
		3.4	Describe cutting techniques used in turning and vertical milling operations
		3.5	Describe the effects of different cuts on the quality of the finished product, production costs and tool life

Learning outcomes		Assessment criteria	
		3.6	Describe the factors that influence the selection of particular cutting speeds, feed and depths of cut when conducting turning and vertical milling operations
		3.7	State how to calculate the correct spindle speeds using given cutting speeds for turning and vertical milling operations
4	Understand quality standards associated with turning and milling operations	4.1	Describe the current quality standards associated with turning and vertical milling operations
		4.2	Define the engineering terms used in quality standards associated with turning and vertical milling operations
		4.3	Describe methods of measuring surface finish for turning and vertical milling operations
		4.4	Describe the advantages of manufacturing components to recognised engineering standards
5	Know how to select, mount and use work holding equipment used in turning and milling operations	5.1	Identify appropriate work holding devices for turning and vertical milling operations
		5.2	Describe how to mount, secure and align work holding devices for turning and vertical milling operations
		5.3	State standard methods of protecting finished surfaces from marking or damage during turning and vertical milling operations
6	Know how to set up and operate a centre lathe and vertical milling machine	6.1	Describe how to set up a centre lathe and vertical milling machine to manufacture components
		6.2	Describe how to use a centre lathe and vertical milling machine to manufacture components
		6.3	State appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the turning and vertical milling operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment and procedures used in turning and milling operations
1A Health and safety requirements associated with turning and vertical milling operations • Duties of employees under current, relevant legislation in relation to turning and vertical milling operations, with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances, environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of a centre lathe and vertical milling machine** • Safety precautions relating to the setting and use of a centre lathe and vertical milling machine, including checking and ensuring that the workpiece is secure and cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for starting/stopping a centre lathe and vertical milling machine under normal conditions and in an emergency. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant. • Use of PPE to include safety glasses, overalls, safety boots, ear defenders.
Learning outcome 2: Understand the function of the tooling and equipment used in turning and milling operations
2A Functions and operation of the component parts and controls of a centre lathe • Component parts of a centre lathe including carriage (saddle and apron), compound slide, cross slide, feed-shaft, guards and covers, including lead screw and chuck, headstock, lathe bed, lead screw, tailstock, tool-post. • Lathe controls including carriage lock, cross feed engagement lever (lateral/tangential), cross slide handle, emergency stop, feed selectors, half-nut lever, longitudinal feed engagement lever, saddle handle, speed selectors, spindle, start/stop lever (forward and reverse), tailstock lock, master isolator.

What needs to be learned

- Functions of the component parts and controls of a centre lathe, e.g. the tailstock, leadscrew, feed shaft, longitudinal feed engagement lever, cross-feed engagement lever.

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

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

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

3A Material properties of cutting tools

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

3B Cutting tool profile

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

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

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

What needs to be learned

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

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

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

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

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

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

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

4A Types of standards in use

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

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

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

What needs to be learned

4C Surface finish measurement

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

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

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

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

5B Methods of protecting finished surfaces from marking or damage

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

Learning outcome 6: Know how to set up and operate a centre lathe and vertical milling machine

6A Setting up a centre lathe for the manufacture of a component

- Operation sequence for the manufacture of a turned component to a given specification.
- Centre lathe set up for the manufacture of a turned component, including start and stop, emergency stop.
- Quality inspections on a manufactured component to ensure compliance with the given specification.

What needs to be learned

6B Setting up a vertical milling machine for the manufacture of a component

- Operation sequence for the manufacture of a component to a given specification.
- Vertical milling machine set up for the manufacture of a component, including start and stop, emergency stop.
- Quality inspections on a manufactured component to ensure compliance with the given specification.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need:

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

Assessment

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

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

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

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

Learning outcome 1

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

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

Learning outcome 2

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

1. describe the function and operation of:
   - **four** of each of the main parts of a centre lathe
   - **four** of each of the main parts of a vertical milling machine
   - **four** controls typically found on a centre lathe
   - **four** controls found on a vertical milling machine (AC2.1, 2.2)
2. describe **three** types of turning and **three** types of vertical milling operation typically carried out on centre lathes and vertical milling machines (AC2.3).

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

Learning outcome 3

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

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

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

Learning outcome 4

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

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

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

Learning outcomes 5 and 6

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

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

Unit 7: Manual Turning Techniques

Level: 2

Unit type: Optional

Guided learning hours: 50

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the equipment and procedures used in turning operations	1.1	Describe the health and safety requirements associated with turning operations
		1.2	Describe the specific safety precautions relating to the setting up and use of a centre lathe
		1.3	Describe centre lathe start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in turning operations	2.1	Explain the functions of the component parts and controls of typical centre lathes
		2.2	Explain the operation of the controls of typical centre lathes
		2.3	Describe the types of operations that can be carried out on a centre lathe
		2.4	Describe types of work holding devices used for turning operations
3	Understand the types and applications of cutting tools used in turning operations	3.1	Describe the properties of cutting tool materials used in turning operations
		3.2	Describe cutting tool profiles using in turning operations
		3.3	Describe the function of the rake and clearance of a single point turning tool
		3.4	Describe cutting techniques used in turning operations
		3.5	Explain the effects of different cuts on the quality of the finished product, production costs and tool life
		3.6	Explain the factors that can influence the rate of material removal when conducting turning operations
		3.7	State how to calculate the correct spindle speeds using given cutting speeds for turning operations
		3.8	Describe the types of cutting fluids that can be used in turning operations

Learning outcomes		Assessment criteria	
		3.9	Explain the effects that cutting fluid has on CNC turning operations
4	Understand quality standards associated with turning operations	4.1	Outline the current quality standards associated with turning operations
		4.2	Define the engineering terms used in quality standards associated with turning operations
		4.3	Describe methods of measuring surface finish for turning operations
		4.4	Outline the advantages of manufacturing components to recognised engineering standards
5	Know how to select, mount and use work holding equipment used in turning operations	5.1	Identify appropriate work holding devices for turning operations
		5.2	Describe how to mount, secure and align work holding devices for turning operations
		5.3	State standard methods of protecting finished surfaces from marking or damage during turning operations
6	Know how to set up and operate a centre lathe	6.1	Describe how to set up a centre lathe to manufacture components
		6.2	Describe how to use a centre lathe to manufacture components
		6.3	State appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the turning operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment and procedures used in turning operations
1A Health and safety requirements associated with turning operations • Duties of employees under relevant legislation with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances. • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of a centre lathe** • The specific safety precautions relating to the setting up and use of a centre lathe, including checking and ensuring that the workpiece is secure and cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping a centre lathe under normal conditions and in an emergency. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant. • Use of PPE, to include safety glasses, apron/overalls, ear protection.
Learning outcome 2: Understand the functions of the tooling and equipment used in turning operations
2A Functions and operation of the component parts and controls of a centre lathe • Centre lathe parts and controls: component parts and controls of a centre lathe, including carriage (saddle and apron), carriage lock, compound slide, cross feed engagement lever (lateral/tangential), cross slide, cross slide handle, emergency stop, feed selectors, feed-shaft, guards and covers including lead screw and chuck, half-nut lever, headstock, lathe bed, lead screw, longitudinal feed engagement lever, saddle handle, speed selectors, spindle, start/stop lever (forward and reverse), tailstock, tailstock lock, tool-post.

What needs to be learned

- Functions of the component parts and controls of a centre lathe, e.g. the tailstock, leadscrew, feed shaft, longitudinal feed engagement lever, cross-feed engagement lever.
- Typical work holding devices, e.g. 3-jaw chuck, 4-jaw chuck, collet chuck, faceplate, centres.

2B Types of operation that can be carried out on a centre lathe

- Centre lathe operations, e.g. plain, stepped and tapered diameters, faces, shoulders, internal and external threads, drilled, bored and reamed holes, chamfers, radii, grooves, undercuts and parting off, knurling.

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

3A Material properties of cutting tools

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

3B Cutting tool profiles

- Centre lathe cutting tool profile types and typical applications, including right and left hand, facing, knife or side cutting, knurling, light turning and facing, parting/grooving/undercutting, radiusing/forming, roughing, threading/ screw cutting, boring bar, twist drill, centre drill, reamer.

3C Rake and clearance of a single point turning tool

- Rake and clearance of a single point turning tool and its function with consideration to the top (or back) rake angle, side rake angle, front (or end) clearance (or relief) angle, side clearance (or relief) angle, side cutting-edge angle, front (or end) cutting-edge angle.
- Relationship between rake and clearance and cutting tool efficiency.

3D Cutting techniques, their effects and the factors that influence the rate of material removal

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

What needs to be learned

3E Calculation of spindle speeds for turning operations

- Correct spindle speeds for turning operations, from given cutting speeds using a suitable formula:

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

Where N = spindle speed, S = cutting speed and D = diameter of material

3F Cutting fluids, types and their effects on machining operations

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

Learning outcome 4: Understand quality standards associated with turning operations

4A Types of standards in use

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

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

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

4C Surface finish measurements

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

What needs to be learned
Learning outcome 5: Know how to select, mount and use work holding equipment used in turning operations
5A Selecting, mounting, securing and aligning work holding devices • Factors to be considered when selecting a work holding device for turning operations, e.g. shape of component to be held, complexity of turning operation, size of the component to be mounted, material properties of the component requiring turning. • Select, safely mount and align suitable work-holding devices to a centre lathe for given machining requirements. **5B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.
Learning outcome 6: Know how to set up and operate a centre lathe

6A Component parts and controls of a centre lathe
• Safe use of the component parts and controls of a centre lathe:
  ○ component parts, including carriage (saddle and apron), compound slide, cross slide, guards and covers, headstock, tailstock, tool-post
  ○ controls, including, emergency stop, feed selectors, speed selectors, spindle, start/stop lever (forward and reverse), tailstock lock, master isolator.
6B Setting up a centre lathe for the manufacture of a component
• Operation sequence for the manufacture of a given turned component, including set up, start and stop, emergency stop.
• Manufacture of a turned component to a given specification.
• Quality inspections on a manufactured component to ensure compliance with the given specification, including visual, dimensional checks, surface finish, recording inspection data.

Essential information for tutors and assessors

Essential resources

For this unit, centres need:

- relevant engineering standards
- engineering workshops containing centre lathes and associated cutting tools and work-holding devices.

Assessment

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

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

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

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

Learning outcome 1

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

1. describe the health and safety requirements for turning operations including duties of employees under current relevant legislation and regulations and environmental considerations (AC1.1)
2. describe the safety precautions that must typically be followed when setting up and using a centre lathe including checks to be carried out before starting the machine, the PPE that must be worn and how to conduct the machine's start/stop procedures in both normal and emergency modes (AC1.2, 1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an illustrated handout for new apprentices that details the parts of a centre lathe. Learners **will**:

1. describe the functions of **four** of the main parts of a centre lathe by annotating a drawing/photograph provided by the tutor (2.1)
2. describe the operation of **four** controls typically found on a centre lathe (AC2.2)
3. describe **three** types of turning operation typically carried out on centre lathes (AC2.3)
4. describe the use of **three** types of work holding device that can be used for turning operations. (AC2.4)

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

Learning outcome 3

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

1. give a clear account of the properties of cutting tool materials used in turning operations (AC3.1)
2. describe **four** cutting tool profiles used in turning operations (AC3.2)
3. describe the function of a rake and clearance of a single point turning tool (AC3.3)
4. describe **three** cutting techniques used in turning operations with details of the effects of applying each technique (AC3.4)
5. explain the effect of different cuts on the quality of the:
    - finished product
    - production costs
    - tool life.

Learners must give **one** valid reason for each (AC3.5).

6. explain **two** factors that can influence the rate of material removal when conducting turning operations (AC3.6)
7. state how to calculate the correct spindle speeds for **two** given turning operations (AC3.7)
8. describe **four** types of cutting fluids used in turning operations and explain the effect these have on CNC turning operations, with relevant examples (AC3.8, 3.9).

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

Learning outcome 4

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

1. provide an overview of the current engineering quality standards that their organisation uses to manufacture components and, using suitable examples, outline the advantages that using these standards offers their workplace during turning operations (AC4.1)
2. define engineering terms used in quality standards associated with turning operations (AC4.2)
3. describe **two** methods that can be used to measure surface finish for **two** given turned components (AC4.3)
4. outline **three** advantages of measuring manufacturing components to recognised engineering standards (AC4.4).

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

Learning outcomes 5 and 6

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

1. identify appropriate work-holding devices for **two** different given turning operations with **one** operation being **straightforward** and **one** being more **complex** (AC5.1)
2. describe how to safely mount the work holding devices, and the appropriate surface protection techniques to use (AC5.2)
3. describe how to safely conduct the turning operations and appropriate inspection techniques to ensure compliance with relevant standards including visual checks, dimensional accuracy and surface finish requirements (AC5.3)
4. describe how to safely conduct the turning and milling operations including setting up and using a centre lathe to manufacture components (AC6.1, 6.2)
5. describe how to use appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements (AC6.3).

Unit 8: Manual Milling Techniques

Level: 2

Unit type: Optional

Guided learning hours: 50

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the equipment and procedures used in milling operations	1.1	Describe the health and safety requirements associated with milling operations
		1.2	Describe the specific safety precautions relating to the setting up and use of a milling machine
		1.3	Describe milling machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in milling operations	2.1	Explain the functions of the component parts and controls of typical milling machines
		2.2	Explain the operation of the controls of typical milling machines
		2.3	Describe the types of operations that can be carried out on a vertical milling machine and a horizontal milling machine
		2.4	Describe the types of work holding devices that can be used during milling operations
3	Understand the types and applications of cutting tools used in milling operations	3.1	Describe the properties of cutting tool materials used in milling operations
		3.2	Describe cutting tool profiles used in milling operations
		3.3	Describe the function of the rake and clearance of a milling cutter
		3.4	Describe cutting techniques used in milling operations
		3.5	Explain the effects of different cuts on the quality of the finished product, production costs and tool life
		3.6	Explain the factors that influence the rate of material removal when conducting milling operations
		3.7	State how to calculate the correct spindle speeds using given cutting speeds for milling operations
		3.8	Describe the types of cutting fluids that can be used in milling operations

Learning outcomes		Assessment criteria	
		3.9	Explain the effects that cutting fluid has on milling operations
4	Understand quality standards associated with milling operations	4.1	Outline the current quality standards associated with milling operations
		4.2	Define the engineering terms used in quality standards associated with milling operations
		4.3	Describe methods of measuring surface finish for milling operations
		4.4	Outline the advantages of manufacturing components to recognised engineering standards
5	Know how to select, mount and use work holding equipment used in milling operations	5.1	Identify appropriate work holding devices for milling operations
		5.2	Describe how to mount, secure and align work holding devices for milling operations
		5.3	State standard methods of protecting finished surfaces from marking or damage during milling operations
6	Know how to set up and operate a milling machine	6.1	Describe how to set up a milling machine to manufacture components
		6.2	Describe how to use a milling machine to manufacture components
		6.3	Describe how to use appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for milling operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment and procedures used in milling operations
1A Health and safety requirements associated with milling operations • Duties of employees under relevant legislation with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances. • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting up and use of a milling machine** • Safety precautions relating to the setting up and use of a milling machine, including checking to ensure that the workpiece is secure and cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping a milling machine under normal conditions and in an emergency. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant. • Use of PPE to include safety glasses, apron/overalls, ear protection.
Learning outcome 2: Understand the functions of the tooling and equipment used in milling operations
2A Functions of the component parts and controls of vertical milling machines • Vertical mill parts and controls: component parts and controls of a vertical milling machine, including start/stop controls, emergency stop, guards, head, motor, drawbar, quill/spindle, quill lock, quill handle, speed change wheel, range change lever, brake, ram, column, table and table locks, table (x-axis) longitudinal traverse handle, saddle and saddle lock, cross (y-axis) traverse handle, power feed (traverse), knee and knee lock, knee crank handle, base. • Functions of the component parts and controls of a vertical milling machine, e.g. quill/spindle, column, range change lever, power feed (traverse), knee crank handle. • Typical work holding devices, e.g. milling vice, vee blocks, angle plates, t-bolts and clamps, rotary dividing table.

What needs to be learned

2B Functions of the component parts and controls of a horizontal milling machine

- Horizontal mill parts and controls, including overarm, drawbar, arbor support/steady, column, spindle, table and table locks, table (x-axis) longitudinal traverse handle, saddle, cross (y-axis) traverse handle, traverse engagement lever, knee and knee lock, knee crank handle, base.
- Functions of the component parts and controls of a horizontal mill, e.g. the spindle, the table, traverse engagement lever, knee crank handle.

2C Types of operation that can be carried out on a milling machine

- Vertical milling machine operations, e.g. flat, parallel and square faces, open ended and enclosed slots, steps/shoulders, drilled, bored and reamed holes.
- Horizontal milling machine operations, e.g. plain milling, straddle milling, gear cutting, gang milling.

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

3A Material properties of cutting tools

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

3B Cutting-tool profile

- Milling machine cutting tool profile types and typical applications, including arbor, chuck and collet mounted types, face mill, end mill, serrated edge end mill, slot drill, ball-nosed slot drill, dove tail cutter, t-slot cutter, woodruff key cutter, corner rounding cutter, slab mill, side and face cutter, single angle cutter, double angle cutter; concave cutter, convex cutter, corner rounding cutter, involute gear tooth cutter, slitting saw.

3C Rake and clearance of a milling cutter

- Rake and clearance of a basic milling cutter and its function with consideration to rake angle, land, primary clearance, secondary clearance.
- Relationship between rake and clearance, and cutting tool efficiency.

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

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

What needs to be learned

- Factors that can influence the rate of material removal, including power and rigidity of a milling machine and work holding devices, cutting fluid, rigidity of the cutting tool and mount, material properties and rigidity of the workpiece, depth of cut, finish required and tool geometry, cutting speed and feed rate.

3E Calculation of spindle speeds for milling operations

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

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

  Where N = spindle speed, S = cutting speed and D = diameter of material

3F Cutting fluids, types and their effects on machining operations

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

Learning outcome 4: Understand quality standards associated with milling operations

4A Types of standards in use

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

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

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

What needs to be learned
4C Surface finish measurements • Methods of measuring surface finish, including contact, surface roughness comparator plates (visual and tactile), electronic roughness tester (stylus type), non-contact, microscopic inspection, e.g. optical microscope. • Units of surface finish and their depiction on engineering drawings.
Learning outcome 5: Know how to select, mount and use work holding equipment used in milling operations
5A Selecting, mounting, securing and aligning work holding devices • Factors to be considered when selecting a work holding device for milling operations, e.g. shape of component to be held, complexity of milling operation, size of the component to be mounted, material properties of the component requiring milling. • Select, safely mount and align suitable work holding devices to a milling machine for given machining requirements. **5B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.
Learning outcome 6: Know how to set up and operate a milling machine
6A Component parts and controls of a vertical milling machine • Safe use of the component parts and controls of a vertical milling machine. • Vertical milling machine component parts including guards, column, table, saddle, knee, base. • Controls of a vertical milling machine, including start/stop controls, emergency stop, speed change wheel, longitudinal traverse handle, master isolator. **6B Component part and controls of a horizontal milling machine** • Safe use of the component parts and controls of a horizontal milling machine. • Horizontal milling machine component parts, including overarm, arbor support/steady, table, saddle, knee, base. • Controls of a horizontal milling machine, including table locks, longitudinal traverse handle, cross (y-axis) traverse handle, traverse engagement lever, knee crank handle.

What needs to be learned

6C Setting up a milling machine for the manufacture of a component

- Operation sequence for the manufacture of a given component, including set up, start and stop, emergency stop of the vertical milling machine.
- Manufacture of a component to a given specification using a milling machine.
- Quality inspections on a manufactured component to ensure compliance with the given specification, including visual, dimensional checks, surface finish, recording inspection data.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need:

- relevant engineering standards
- engineering workshops containing horizontal and vertical milling machines
- appropriate cutting tools and work holding devices.

Assessment

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

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

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

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

Learning outcome 1

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

1. describe the health and safety requirements for manual milling techniques including duties of employees under current relevant legislation and environmental considerations (AC1.1)
2. describe the safety precautions that must typically be followed when setting up a milling machine including checks to be carried out before starting the machine, the PPE to wear and how to conduct the machine start/stop procedures in both normal and emergency modes (AC1.2, 1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an illustrated handout for new apprentices that details the parts of both horizontal and vertical milling machines. Learners **will**:

1. annotate drawings/photographs provided by the tutor to show:
   - the functions of **four** of the main parts of a horizontal milling machine
   - the functions of **four** of the main parts of a vertical milling machine (AC2.1)
2. describe the function and operation of:
   - **four** controls typically found on a horizontal milling machine
   - **four** controls typically found on a vertical milling machine (AC2.1, 2.2)
3. describe **three** types of milling operation typically carried out on horizontal milling machines and **three** operations typically carried out on vertical milling machines (AC2.3)
4. describe the use of **three** types of work holding device that can be used for milling operations (AC2.4).

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

Learning outcome 3

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

1. give a clear account of at least **three** properties of cutting-tool materials used in milling operations (AC 3.1)
2. describe cutting tool profiles used in milling operations. Learners must give a clear account of at least **four** cutting tools and their profile types (AC3.2)
3. describe the function of the rake and clearance of a milling cutter. Learners must give details of the considerations when using these tools (AC3.3)
4. describe cutting techniques used in milling operations. Learners must include details of the effects of using these techniques (AC3.4, 3.5)
5. explain **four** factors that influence the rate of material removal when conducting milling operations, with a relevant example for each factor (AC3.6)
6. state how to calculate the spindle speeds for given cutting speeds required for **four** given milling operations (AC3.7)
7. describe **three** types of cutting fluids that can be used during machining operations and explain the effects that cutting fluids have on cutting operations (AC3.8, 3.9).

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

Learning outcome 4

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

1. provide an overview of the current engineering quality standards that their workplace uses when carrying out milling operations (AC4.1)
2. define engineering terms used in quality standards associated with milling operations (AC4.2)
3. describe **two** methods that can be used to measure surface finish for **two** given milled components (AC4.3)
4. outline the advantages that using these standards offers their workplace using suitable examples (AC4.4).

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

Learning outcomes 5 and 6

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

1. identify appropriate work holding devices for **two** different given milling operations using a **vertical milling machine** with **one** operation being **straightforward** and **one** being more **complex** (AC5.1)
2. identify appropriate work holding devices for **one** given milling operation using a **horizontal milling machine** (AC5.1)
3. describe how to safely mount the work holding devices, including appropriate surface protection techniques (AC5.2)
4. describe how to safely conduct the vertical and horizontal milling operations and to use appropriate inspection techniques to ensure compliance with relevant standards including visual checks, surface finish requirements and dimensional accuracy (AC5.3)

5. describe how to safely set up and operate a milling machine to manufacture components (AC6.1, 6.2)
6. describe appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements (AC6.3).

   Where possible, learners would benefit from undertaking these activities in their own workplace.

Unit 9: Principles of Computer Numerical Control (CNC) Milling and Turning

Level: 2

Unit type: Optional

Guided learning hours: 80

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the equipment, procedures and relevant safety precautions used in CNC milling and turning operations	1.1	Describe the health and safety requirements associated with CNC turning and milling operations
		1.2	Describe the safety precautions relating to the setting and use of a CNC lathe and milling machine
		1.3	Describe CNC lathe and milling machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in CNC milling and turning operations	2.1	Describe the functions and operation of the component parts and controls of typical CNC lathes
		2.2	Describe the functions and operation of the component parts and controls of typical CNC milling machines
		2.3	Describe the types of turning and milling operations that can be carried out on a CNC lathe and milling machine
		2.4	Describe types of work holding device that can be used for both CNC turning and CNC milling operations
3	Understand the types and applications of cutting tools used in CNC milling and turning operations	3.1	Describe the properties of cutting tool materials used in CNC milling and turning operations
		3.2	Explain the factors that influence cutting tool selection for CNC milling and turning operations
		3.3	Describe cutting tool profiles used in CNC milling and turning operations
		3.4	Describe the function of the rake and clearance of a CNC single point turning tool and a milling cutter
		3.5	Describe cutting techniques used in CNC turning and milling operations

Learning outcomes		Assessment criteria	
		3.6	Explain the effects of different cuts on the quality of the finished product, production costs and tool life
		3.7	Explain the factors that influence the selection of particular cutting speeds, feed and depths of cut when conducting turning and milling operations
		3.8	State how to determine correct CNC machine running parameters for turning and milling operations
		3.9	Describe the types of cutting fluids that can be used in milling and turning operations
		3.10	Describe the effects that cutting fluid has on milling and turning operations
4	Understand basic CNC milling and turning operations and programming	4.1	Define the term 'computer numerical control'
		4.2	Describe the benefits of CNC control over conventional milling and turning techniques
		4.3	Define the term 'part program' and associated basic part programming terminology
		4.4	Describe the methods of inputting data into a CNC controller
		4.5	Describe how to prepare a basic part program
		4.6	Describe the methods used to prove a part program
		4.7	Explain the reasons for proving a part program
		4.8	Describe how to deal with program errors
5	Understand quality standards associated with CNC milling and turning operations	5.1	Describe methods of measuring surface finish for turning and milling operations
		5.2	Outline the current quality standards associated with turning and milling operations
		5.3	Define the engineering terms used in quality standards associated with turning and milling operations
6	Know how to select, mount and use work holding	6.1	Identify appropriate work holding devices for turning and milling operations
		6.2	Describe how to mount, secure and align work holding devices for turning and milling operations

Learning outcomes		Assessment criteria	
	equipment used in CNC milling and turning operations	6.3	State standard methods of protecting finished surfaces from marking or damage during turning and milling operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment, procedures and relevant safety precautions used in CNC milling and turning operations
1A Health and safety requirements associated with CNC milling and turning operations • Duties of employees under relevant current legislation with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances. • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of CNC machines** • Safety precautions relating to the setting and use of a CNC lathe and milling machine, including checking and ensuring that the workpiece is secure and that cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping a CNC machine under normal conditions and in an emergency. • Fitting and adjustment of machine guarding and interlocks. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant, use of PPE to include safety glasses.
Learning outcome 2: Understand the function of the tooling and equipment used in CNC milling and turning operations
2A Functions and operation of the component parts and controls of CNC lathes • CNC lathe parts and controls: component parts and controls of a CNC lathe, including start/stop controls, tool turret, saddle, bed/slant bed, headstock, spindle, cross slide, tailstock, servo-motors, controller, emergency stop, base, coolant pump, fully enclosed interlocking guarding. • Functions of the component parts and controls of a CNC lathe, e.g. the tailstock, tool turret, saddle, headstock.

What needs to be learned

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

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

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

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

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

3A Selection and properties of cutting tools

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

3B Cutting-tool profile

- CNC lathe cutting tool profile types and typical applications, including roughing tool, finishing tool, parting-off tool, screw thread tool, profiling tools, form tools, centre drills, twist/core drills, boring tools, reamers, maxi-tipped drills, carbide insert drills.

What needs to be learned

- CNC milling machine cutting tool profile types and typical applications, including arbor, chuck and collet mounted types (as applicable), face mill, end mill, serrated edge end mill, slot drill, ball-nosed cutters, dovetail cutter, t-slot cutter, woodruff key cutter, corner rounding cutter, boring tool, fly cutter, twist drill, centre drill and reamer, special profile cutters.

3C Rake and clearance of CNC milling and turning tools

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

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

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

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

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

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

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

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

What needs to be learned

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

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

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

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

- Definition of computer numerical control (CNC).

4B Benefits of CNC milling and turning operations

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

4C Part program and associated terminology

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

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

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

What needs to be learned

Learning outcome 5: Understand quality standards associated with CNC milling and turning operations

5A Surface finish measurements

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

5B Types of quality standards in use

- Requirements of the current standards in use, including British Standards (BS), European Standards (EN), International Standards Organisation (ISO) with consideration to physical standards, international system of units (SI), National Physical Laboratory (NPL), United Kingdom Accreditation Service (UKAS), primary and secondary calibration standards, calibration certificates, standard specifications.
- Definition of engineering terms used in quality standards for CNC turning and milling operations: definitions; to include tolerance, limits of size, limits and fits, classes of fit, including clearance, transition and interference.

Learning outcome 6: Know how to select, mount and use work holding equipment used in CNC milling and turning operations

6A Selecting, mounting, securing and aligning work holding devices

- Factors to be considered for CNC milling and turning operations, e.g. shape of component to be held, complexity of the milling or turning operation, size of the component to be mounted, material properties of the component requiring milling or turning.
- Select, safely mount and align suitable work holding devices to a CNC lathe and CNC milling machine for given milling and turning requirements.

6B Methods of protecting finished surfaces from marking or damage

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

Essential information for tutors and assessors

Essential resources

For this unit, centres need:

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

Assessment

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

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

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

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

Learning outcome 1

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

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

Learning outcome 2

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

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

Learning outcome 3

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

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

Learning outcome 4

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

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

Learning outcome 5

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

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

Learning outcome 6

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

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

Unit 10: Computer Numerical Control (CNC) Turning Techniques

Level: 2

Unit type: Optional

Guided learning hours: 50

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the equipment and procedures used in CNC turning operations	1.1	Describe the health and safety requirements associated with turning operations
		1.2	Describe the specific safety precautions relating to the setting up and use of a CNC lathe machine
		1.3	Describe CNC lathe machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in CNC turning operations	2.1	Describe the functions of the component parts and controls of typical CNC lathes
		2.2	Describe the operation of the controls of typical CNC lathes
		2.3	Describe the types of operations that can be carried out on a CNC lathe
3	Understand the types and applications of cutting tools used in CNC turning operations	3.1	Describe the properties of cutting tool materials used in CNC turning operations
		3.2	Describe the factors that influence cutting tool selection
		3.3	Describe cutting tool profiles used in CNC turning operations
		3.4	Describe the function of the rake and clearance of a CNC single point turning tool
		3.5	Describe cutting techniques used in CNC turning operations
		3.6	Explain the effects of different cuts on the quality of the finished product, production costs and tool life
		3.7	Describe the factors that influence the rate of material removal when conducting CNC turning operations
		3.8	State how to calculate correct CNC machine running parameters for turning operations
		3.9	Describe the types of cutting fluids that can be used in CNC turning operations
		3.10	Explain the effects that cutting fluid has on CNC turning operations

Learning outcomes		Assessment criteria	
4	Understand basic CNC turning operations and programming	4.1	Define the term 'computer numerical control'
		4.2	Describe the benefits of CNC control over conventional machining techniques
		4.3	Define the term 'part program' and associated basic part programming terminology
		4.4	Describe the methods of inputting data into a CNC controller
5	Understand quality standards associated with CNC turning operations	5.1	Outline the current quality standards associated with turning operations
		5.2	Define the engineering terms used in quality standards associated with turning operations
		5.3	Describe methods of measuring surface finish for turning operations
		5.4	Outline the advantages of manufacturing components to recognised engineering standards
6	Know how to select, mount and use work-holding equipment used in CNC turning operations	6.1	Identify appropriate work holding devices for turning operations
		6.2	Describe how to mount, secure and align work holding devices for turning operations
		6.3	State standard methods of protecting finished surfaces from marking or damage during turning operations
7	Know how to set up and operate CNC devices for turning operations	7.1	Describe how to set up a CNC lathe to manufacture components
		7.2	Describe how to use a CNC lathe to manufacture components
		7.3	State appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the turning operations
		7.4	Outline the relevant documentation used to record inspection data and organisational procedures to be followed

Learning outcomes		Assessment criteria	
8	Know how to produce, prove and troubleshoot a part program for given CNC turning operations	8.1	Describe how to produce a basic part program for a given CNC turning operation
		8.2	Outline how to prove a part program used for a given CNC turning operation
		8.3	Describe how to troubleshoot a basic part program for given CNC operations

Unit content

What needs to be learned
Learning outcome 1: Understand the equipment and procedures used in CNC turning operations
1A Health and safety requirements associated with CNC turning operations • Duties of employees under relevant legislation with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances. • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting and use of CNC machines** • The specific safety precautions relating to the setting and use of a CNC lathe, including checking and ensuring that the workpiece is secure and cutting tools are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping a CNC machine under normal conditions and in an emergency. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of coolant. • Use of PPE to include safety glasses, apron/overalls, ear protection.
Learning outcome 2: Understand the functions of the tooling and equipment used in CNC turning operations
2A Functions and operation of the component parts and controls of CNC lathes • CNC lathe parts: saddle, bed/slant bed, headstock, spindle, cross slide, tailstock, servo motors, tool turret, base, coolant pump. • Component parts and controls of a CNC lathe, including start/stop controls, controller, emergency stop, fully enclosed interlocking guarding. • Functions of the component parts and controls of a CNC lathe, e.g. the tailstock, tool turret, saddle, headstock, controller, emergency stop.

What needs to be learned

2B Types of operation that can be carried out on CNC lathes

- CNC lathe operations, including plain, parallel, stepped, tapered and eccentric diameters, flat faces, internal and external profiles, internal and external screw threads, drilled holes, tapped, bored and reamed holes, chamfers, radii, undercuts and parting off.

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

3A Material properties of cutting tools

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

3B Cutting tool profile

- CNC lathe cutting tool profile types and typical applications, including roughing tool, finishing tool, parting-off tool, screw thread tool, profiling tools, form tools, centre drills, twist/core, drills, boring tools, reamers, maxi-tipped drills, carbide insert drills.

3C Rake and clearance of CNC turning tools

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

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

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

What needs to be learned

- Factors influencing the rate of material removal, including power and rigidity of the lathe and work holding devices, cutting fluid, rigidity of the cutting tool and mount, material properties and rigidity of the workpiece, depth of cut, finish required and tool geometry.

3E Determination of correct CNC machine running parameters for turning operations

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

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

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

- Correct cutting speeds and feed rates for CNC turning operations using cutting tool manufacturer's data tables.

3F Cutting fluids, types and their effects on machining operations

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

Learning outcome 4: Understand basic CNC turning operations and programming

4A Definition 'computer numerical control'

- Definition of the term 'computer numerical control (CNC)'
- Functions and motions of a machine tool that can be controlled using CNC, including motions of the workpiece or tool, the input parameters such as the feed, depth of cut, speed, and functions as turning/milling spindle on/off, turning/milling coolant on/off.

4B Benefits of CNC control

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

What needs to be learned

4C Part program and associated terminology

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

4D Loading part program into a CNC controller

- Methods of loading a part program into a CNC controller, including manual data input (MDI), storage/transfer from media such as disk, CD-ROM, USB flash drive or portable external hard drive, Direct Numerical Control (DNC) such as RS 232 link, wireless or wired network (ethernet).

Learning outcome 5: Understand quality standards associated with CNC turning operations

5A Types of standards in use

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

5B Typical engineering terms used in quality standards for CNC turning operations

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

5C Surface finish measurements

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

What needs to be learned
Learning outcome 6: Know how to select, mount and use work holding equipment used in CNC turning operations
6A Selecting, mounting, securing and aligning work holding devices • Factors to be considered when selecting a work holding device for CNC turning operations, e.g. shape of component to be held, complexity of the turning operation, size of the component to be mounted, material properties of the component requiring turning. • Select, safely mount and align suitable work holding devices to a CNC lathe for given machining requirements. **6B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.
Learning outcome 7: Know how to set up and operate CNC devices for turning operations
7A Safe use of component parts and controls of a CNC lathe • CNC lathe parts: saddle, bed/slant bed, headstock, spindle, cross slide, tailstock, servo-motors, tool turret, base, coolant pump. • Controls: component parts and controls of a CNC lathe, including start/stop controls, controller**,** emergency stop, fully enclosed interlocking guarding. **7B Setting up a CNC lathe for the manufacture of a component** • Operation sequence for the manufacture of a given turned component, including setting up a CNC lathe, loading a part program into the CNC controller and proving the program, start and stop, emergency stop. • Manufacture of a turned component to a given specification. • Quality inspections on a manufactured component to ensure compliance with the given specification.
Learning outcome 8: Know how to produce, prove and troubleshoot a part program for given CNC turning operations
8 Preparing a part program, proving and loading into a CNC machine • Produce part programs using engineering documentation, including planning requirements such as analysis of the working drawing, preparing a work plan, set up, including material, tooling and work holding, writing a part program

What needs to be learned
• Methods of loading a part program into a CNC controller, including manual data input (MDI), storage/transfer from media such as disk, CD-ROM, USB flash drive or portable external hard drive, Direct Numerical Control (DNC) such as RS 232 link, wireless or wired network (ethernet). • Reasons for and methods of proving a part program, including single block run, dry run, feed and speed override controls. • Dealing with error codes before making the first cut.

Essential information for tutors and assessors

Essential resources

For this unit, centres need relevant engineering standards, tool-manufacturer data tables, engineering workshops containing CNC lathes and associated cutting tools and work-holding devices.

Assessment

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

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

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

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

Learning outcome 1

To satisfy the assessment criteria for this learning outcome, learners produce a handout to share with their colleagues that gives details of the health and safety implications of operating CNC lathes in an engineering organisation.
Learners **will**:

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

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an illustrated handout for new apprentices that details the parts of a CNC lathe.
Learners **will**:

1. give a clear account of the functions of **four** of the main parts of a CNC lathe, and the function of **four** controls typically found on a CNC lathe by annotating a labelled drawing/photograph provided by the tutor or employer (AC2.1, 2.2)
2. describe **three** types of turning operation typically carried out on CNC lathes (2.3).

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

Learning outcome 3

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

1. give a clear account of at least **three** properties of cutting tool materials used in CNC turning operations (AC 3.1)
2. describe **three** factors that influence cutting tool selection (AC3.2)
3. describe **four** types of cutting tool profile used in turning operations. Learners must include details of **four** cutting tools and their profiles (AC3.3)
4. describe **three** functions of cutting tool rake and clearance by annotating diagrams provided by the tutor (AC3.4)
5. describe **two** types of cutting techniques used in CNC turning operations (AC3.5)

6. explain the effects that these cuts have on production costs, tool life and the quality of the components produced (AC3.6)
7. describe **four** factors influencing the rate of material removal when conducting CNC turning operations (AC3.7)
8. state how to calculate the spindle speeds and the cutting and feed rates required for **two** given CNC turning operations (AC3.8)
9. describe **three** types of cutting fluids that can be used during CNC turning operations and explain the effects that cutting fluids have on cutting operations (AC3.9, 3.10).

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

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce a leaflet to give to new employees detailing CNC machining principles and terminology. Learners **will**:

1. define the term 'computer numerical control' (AC4.1)
2. describe **four** benefits of CNC machining over conventional machining techniques (AC4.2)
3. specify the meaning of the term 'part program' and **four** associated CNC engineering terms (AC4.3)
4. give a clear account of **two** methods of inputting data into a CNC controller (AC4.4).
5. Where possible, learners will need to provide clear examples specific to their own workplace.

Learning outcome 5

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

1. give an overview of the requirements of the current quality standards associated with turning operations (AC5.1)
2. define **three** engineering terms used in quality standards associated with CNC turning operations (AC5.2)
3. describe **two** methods that can be used to measure surface finish for **two** given turned components (AC5.3)

4. briefly describe **three** advantages that using these standards offers their workplace during manufacture of components (AC5.4).

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

Learning outcomes 6, 7 and 8

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

1. identify appropriate work holding devices for **two** different given turning operations with **one** being **straightforward** and **one** being more **complex** (AC6.1)
2. describe how to safely mount the work holding devices, stating clearly the surface protection techniques used (AC6.2, 6.3)
3. describe how to safely conduct the turning operations including setting up and using an CNC lathe to manufacture components. Learners will include details of appropriate visual inspection techniques of dimensions and surface finish to be used to ensure compliance with relevant standards and surface finish requirements
   (AC7.1, 7.2)
4. describe appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the turning operations (AC7.3)
5. give an overview of the relevant documents used to record inspection data and the organisational procedures followed (AC7.4)
6. describe how to produce and prove part programs for **two** different given turning operations with **one** being **straight forward** and **one** being more **complex**. Learners will include a clear account of how to troubleshoot basic part programs for a given CNC operation. Learners will need to provide supporting evidence, such as annotated screenshots, of the part programs, describing how the programs are expected to operate (AC8.1, 8.2, 8.3).

Unit 11: Computer Numerical Control (CNC) Milling Techniques

Level: 2

Unit type: Optional

Guided learning hours: 50

Unit introduction

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

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

Learning outcomes and assessment criteria

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

Learning outcomes		Assessment criteria	
1	Understand the equipment and procedures used in CNC milling operations	1.1	Describe the health and safety requirements associated with CNC milling operations
		1.2	Describe the specific safety precautions relating to the setting up and use of a CNC milling machine
		1.3	Describe milling machine start/stop procedures in both normal and emergency mode
2	Understand the functions of the tooling and equipment used in CNC milling operations	2.1	Describe the functions of the component parts and controls of typical CNC milling machines
		2.2	Describe the operation of the controls of typical CNC milling machines
		2.3	Describe the types of operations that can be carried out on a CNC milling machine
3	Understand the types and applications of cutting tools used in CNC milling operations	3.1	Describe the properties of cutting tool materials used in CNC milling operations
		3.2	Explain the factors that influence cutting tool selection used in CNC milling operations
		3.3	Describe cutting tool profiles used in CNC milling operations
		3.4	Describe the function of the rake and clearance of a CNC milling cutter
		3.5	Describe cutting techniques used in CNC milling operations
		3.6	Describe the effects of different cuts on the quality of the finished product, production costs and tool life
		3.7	Explain the factors that influence the rate of material removal when conducting CNC milling operations

Learning outcomes		Assessment criteria	
		3.8	State how to calculate correct CNC machine running parameters for CNC milling operations
		3.9	Describe the types of cutting fluids that can be used in CNC milling operations
		3.10	Describe the effects that cutting fluid has on CNC milling operations
4	Understand basic CNC milling operations and programming	4.1	Define the term 'computer numerical control'
		4.2	Describe the benefits of CNC control over conventional machining techniques
		4.3	Define the term 'part program' and associated basic part programming terminology
		4.4	Describe the methods of inputting data into a CNC controller
5	Understand quality standards associated with CNC milling operations	5.1	Outline the current quality standards associated with milling operations
		5.2	Define the engineering terms used in quality standards associated with milling operations
		5.3	Describe methods of measuring surface finish for milling operations
		5.4	Outline the advantages of manufacturing components to recognised engineering standards
6	Know how to select, mount and use work holding equipment used in CNC milling operations	6.1	Identify appropriate work holding devices for milling operations
		6.2	Describe how to mount, secure and align work holding devices for milling operations
		6.3	State standard methods of protecting finished surfaces from marking or damage during milling operations

Learning outcomes		Assessment criteria	
7	Know how to set up and operate CNC devices for milling operations	7.1	Describe how to set up a CNC milling machine to manufacture components
		7.2	Describe how to use a CNC milling machine to manufacture components
		7.3	State appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for the milling operations
8	Know how to produce, prove and troubleshoot a part program for given CNC milling operations	8.1	Describe how to produce a basic part program for a given CNC milling operation
		8.2	Describe how to prove a part program used for a given CNC milling operation
		8.3	Describe how to troubleshoot a basic part program for given CNC operations

What needs to be learned

Learning outcome 1: Understand the equipment and procedures used in CNC milling operations

1A Health and safety requirements associated with CNC milling operations

- Duties of employees under relevant legislation with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances.
- Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults.

1B Safety precautions relating to the setting up and use of CNC milling machines

- Specific safety precautions relating to the setting up and use of a CNC milling machine, including checking and ensuring that the workpiece is secure and cutting tools are free from damage and clear of the workpiece before starting the machine.
- Safe working practices and procedures to include procedures for start/stopping a CNC milling machine under normal conditions and in an emergency.
- Fitting and adjustment of machine guarding.
- Mounting work holding equipment and the workpiece safely.
- Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks.
- Use of coolant.
- Use of PPE, to include safety glasses, apron/overalls, ear protection.

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

2A Functions and operations of the component parts and controls of CNC milling machines

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

What needs to be learned
2B Types of operations that can be carried out on CNC milling machines • CNC milling machine operations, including flat, parallel and square faces, open ended and enclosed slots/recesses and pockets, steps/shoulders, angular faces, drilled, reamed and tapped holes (linear and circular pitched), bored holes, indexed and rotated forms, internal/concave and external/convex profiles, special forms, such as gear forms and serrations.
Learning outcome 3: Understand the types and applications of cutting tools used in CNC milling operations
3A Material properties of cutting tools • Properties of cutting tool materials, including Tungsten carbide, ceramic and diamond indexable tipped tooling, e.g. hardness, wear resistance, toughness, temperature resistance. • Factors that determine their selection and use such as condition of material supplied, hardness of the material, tolerances to be achieved, component surface finish and specifications. **3B Cutting tool profile** • CNC milling machine cutting tool profile types and typical applications, including arbor, chuck and collet mounted types (as applicable), face mill, end mill, serrated edge end mill, slot drill, ball-nosed cutters, dovetail cutter, t-slot cutter, woodruff key cutter, corner rounding cutter, boring tool, fly cutter, twist drill, centre drill and reamer, special profile cutters. **3C Rake and clearance of CNC milling tools** • Rake and clearance of a milling cutter and its function with consideration to rake angle, land, primary clearance, secondary clearance. • Functions of tool rake and clearance angles with consideration to effective cutting, influence on chip formation, positive and negative rake, prevention of rubbing, how rake and clearance angles may vary, including cutting tool type, cutting tool material and the material being cut. **3D Cutting techniques, their effects and the factors that influence the cutting speed** • Effects of applying roughing, finishing and trial cuts, including minimising production costs, achieving the required dimensional accuracy, achieving the required surface finish, the effects that roughing and finishing cuts have on cutting tool life, surface finish and dimensional accuracy.

What needs to be learned

- Factors influencing the rate of material removal, including power and rigidity of the lathe or milling machine and work holding devices, cutting fluid, rigidity of the cutting tool and mount, material properties and rigidity of the workpiece, depth of cut, finish required and tool geometry, cutting speed and feed rate.

3E Determination of correct CNC machine running parameters for milling operations

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

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

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

- Correct cutting speeds and feed rates for CNC milling operations using cutting tool manufacturer's data tables.

3F Cutting fluids, types and their effects on machining operations

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

Learning outcome 4: Understand basic CNC milling operations and programming

4A Definition of computer numerical control

- Definition of 'computer numerical control (CNC)'.
- Functions and motions of a machine tool that can be controlled using CNC, including motions of the workpiece or tool, the input parameters such as the feed, depth of cut, speed, and functions such as milling spindle on/off, milling coolant on/off.

4B Benefits of CNC control

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

What needs to be learned

4C Part program and associated terminology

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

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

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

Learning outcome 5: Understand quality standards associated with CNC milling operations

5A Types of standards in use

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

5B Typical engineering terms used in quality standards for CNC milling operations

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

What needs to be learned
5C Surface finish measurements • Methods of measuring surface finish, including contact, surface roughness comparator plates (visual and tactile), electronic roughness tester (stylus type), non-contact, microscopic Inspection, e.g. optical microscope. • Units of surface finish and their depiction on engineering drawings.
Learning outcome 6: Know how to select, mount and use work holding equipment used in CNC milling operations
6A Selecting, mounting, securing and aligning work holding devices • Factors to be considered when selecting a work holding device for CNC milling operations, e.g. shape of component to be held, complexity of the milling operation, size of the component to be mounted, material properties of the component requiring milling. • Select, safely mount and align suitable work holding devices to a CNC milling machine for given machining requirements. **6B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces' content.
Learning outcome 7: Know how to set up and operate CNC devices for milling operations
7A Component parts and controls of a CNC milling machine • Safe use of the component parts and controls of a CNC milling machine. • CNC milling machine parts, including (as appropriate to the machine) guards, motor, head, power/automated drawbar, machine spindle, tool carousel, column, table, saddle, slideways, bed, fully enclosed interlocking guarding, servo-motors, coolant pump. • Controls, including (as appropriate to the machine) master isolator, start/stop controls, emergency stop, controller. **7B Setting up a CNC milling machine for the manufacture of a component** • Operation sequence for the manufacture of a given turned component, including setting up a CNC milling machine, loading a part program into the CNC controller and proving the program, start and stop, emergency stop. • Manufacture of a milled component to a given specification.

What needs to be learned
• Quality inspections on a manufactured component to ensure compliance with the given specification, e.g. inspection record, visual checks, dimensional, surface finish, recording of inspection data.
Learning outcome 8: Know how to produce, prove and troubleshoot a part program for given CNC milling operations
8A Preparing a part program, proving and loading into a CNC machine • Produce part programs using engineering documentation, including planning requirements such as analysis of the working drawing, preparing a work plan, set up, including material, tooling and work holding, writing a part program. • Methods of loading a part program into a CNC controller, including manual data input (MDI), storage/transfer from media such as disk, CD-ROM, USB flash drive or portable external hard drive, Direct Numerical Control (DNC) such as RS 232 link, wireless or wired network, ethernet. • Methods of proving a part program, including single block run, dry run, feed and speed override controls. • Dealing with error codes before making the first cut.

Essential information for tutors and assessors

Essential resources

For this unit, centres will need:

- relevant engineering standards
- tool manufacturer data tables
- engineering workshops containing CNC milling machines
- appropriate cutting tools and work holding devices.

Assessment

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

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

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

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

For further detail, please refer to the guidance on selecting suitable assessment activities for the skills units, available on our website.

Learning outcome 1

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

1. describe the health and safety requirements associated with CNC milling machines including the duties of employees under relevant legislation and environmental considerations (AC1.1)

2. describe the safety precautions that must typically be followed when setting up and using a CNC milling machine including checks to be carried out before starting the machine, the PPE that must be worn and how to conduct the machine start/stop procedures in both normal and emergency modes (AC1.2, 1.3).

Learning outcome 2

To satisfy the assessment criteria for this learning outcome, learners produce an illustrated handout for new apprentices that details the parts of a CNC milling machine. Learners **will**:

1. give a clear account of the functions of **four** of the main parts of a CNC milling machine using a labelled drawing/photograph provided by the tutor or employer (AC2.1)
2. Give a clear account of the functions of **four** controls typically found on a CNC milling machine (AC2.2)
3. describe **three** types of milling operation typically carried out on CNC milling machines (AC2.3).

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

Learning outcome 3

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

1. describe the properties of cutting tool materials used in CNC milling operations, and explain **three** factors that need to be considered when selecting them for use with **one** valid reason for each factor (AC3.1, 3.2)
2. describe **four** types of cutting tool profile used in turning operations by annotating diagrams provided by the tutor, and describe **three** functions of cutting tool rake and clearance (AC3.3, 3.4)
3. describe the **three** types of cuts that are commonly used in CNC milling operations and the effects that these cuts have on the quality of the components produced (AC3.5, 3.6)
4. explain **four** factors that influence the rate of material removal when conducing CNC milling operations with **one** valid reason for each factor (AC3.7)
5. state how to calculate the spindle speeds and the cutting and feed rates required for **two** given CNC turning operations (AC3.8)

6. describe **three** types of cutting fluids that can be used during CNC machining operations and explain the effects that cutting fluids have on cutting operations with examples (AC3.9, 3.10).

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

Learning outcome 4

To satisfy the assessment criteria for this learning outcome, learners produce a leaflet to give to new employees detailing CNC machining principles and terminology. Learners **will**:

1. give the meaning of the term 'computer numerical control' (AC4.1)
2. describe **three** benefits of CNC machining over conventional machining techniques (AC4.2)
3. give the meaning of the term 'part program' and **four** associated CNC engineering terms (AC4.3)
4. describe **two** methods of inputting data into a CNC controller (AC4.4).

Learning outcome 5

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

1. give an overview of the requirements of the current quality standards associated with milling operations (AC5.1)
2. define engineering terms used in quality standards associated with CNC milling operations (AC5.2)
3. describe **two** methods of measuring surface finish for **two** given milled components. (AC5.3)
4. give an overview of the advantages of manufacturing components to recognised engineering standards (AC5.4).

Learning outcomes 6, 7 and 8

To satisfy the assessment criteria for these learning outcomes, learners relate their evidence to **two** given CNC milling operations. Learners will refer to evidence from practical activities they have undertaken including a completed logbook (including photographic evidence) and quality inspection records to demonstrate their knowledge of grinding operations. Where possible, learners undertake these activities within their own workplace, or if they are not in employment, in a realistic work environment. It is expected that learning outcomes 6, 7 and 8 will be assessed alongside each other. Learners will:

1. identify appropriate work holding devices for **two** different given milling operations with **one** being **straightforward** and **one** being more **complex** (AC6.1)
2. give a clear account of how to safely mount the work holding devices, demonstrating surface protection techniques as appropriate (AC6.2)
3. briefly describe the standard methods of protecting finished surfaces from marking or damage during milling operations (AC6.3)
4. describe how to safely conduct the CNC milling operations including setting up and using a CNC milling machine to manufacture components, including appropriate visual inspection techniques of dimensions and surface finish to ensure compliance with relevant standards and surface finish requirements (AC7.1, 7.2)
5. describe appropriate inspection techniques to ensure compliance with relevant standards and surface finish requirements for milling operations including the inspection data to be recorded, and the relevant documentation, as applicable to their place of work (AC7.3)
6. describe how to produce part programs for **two** different given milling operations with **one** being **straightforward** and **one** being more **complex** (AC8.1)
7. describe how to prove the part programs produced for the given milling operations (AC8.2)
8. describe how to troubleshoot the part programs produced in order to eliminate any errors in the program or problems with the CNC milling operation (AC8.3).

   Learners will need to provide supporting evidence such as annotated screenshots of the part programs describing how the programs are expected to operate.

Unit 12: Computer Aided Design

Level: 2

Unit type: Optional

Guided learning hours: 90

Unit introduction

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

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

Learning outcomes and assessment criteria

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

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

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

What needs to be learned

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

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

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

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

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

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

2A CAD configurable drawing parameters

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

2B Benefits and limitations

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

What needs to be learned
Learning outcome 3: Understand the need to comply with national and international drawing standards
3A Requirement for drawing standards • Commonality of drawing interpretation. • Removal of language barriers – use of symbology. • Global manufacture of component parts assembled in one location. **3B Features and symbols** • Use of 1st and 3rd angle projection. • Features used in engineering drawings, e.g. symbols, lettering and numbering, line types, dimensioning. • Units of measurement, e.g. metric, imperial, angular. • Symbols utilised in engineering drawings, e.g. welding, electrical/electronic, mechanical, fluid power.
Learning outcome 4: Understand how to use CAD software for the production of 2D and 3D industry standard engineering drawings
4A Software requirements and key features • Reference point. • Ease of use. • Software and hardware compatibility. • Coordinate input methods, e.g. absolute, relative/incremental, polar. • Drawing aids, e.g. coordinate grids and snaps, object snaps, viewing features, e.g. zoom, previous, pan. **4B Drawing features** • Geometry, e.g. lines, circles, arcs, ellipses. • Dimensioning, including linear dimensions, radial dimensions, angular dimensions, leaders' dimensions, text dimensions, tolerance dimensions. • Text, including text location, font type, size and orientation. **4C Drawing features of 3D CAD models** • 3D features of engineering components, including: threads – male and female, holes – plain, drilled, threads, countersunk, fillet, chamfer, combination of solid objects, including Boolean operations. • Placing 3D components, including degrees of freedom, XYZ translational freedom and XYZ rotational freedom.

What needs to be learned
• Assembly constraints and the relationships between components, including mate constraint and angle constraint assembly relationships, insert constraint and tangent constraint assembly relationships. • Modification to 3D components due to assembly constraints. • Consideration of assembly, including storyboarding, component relationship. • Use of rendering, including render, shadows, reflections, lights, materials, textures, ray tracing. **4C Key features of 3D CAD software** • Configuration of the parametric modeller, including origin, units, snap and grid, correct format, project files, selection of file types, and planes, e.g. XY, XZ and YZ. • Use of display commands, including pan, zoom, and orbit.
Learning outcome 5: Understand how to use layers, copy, modify and manipulate drawn entities to maintain drawing efficiency
5A Layers • Importance of the use of layers in CAD. • Definition of a layer. • Requirements of efficient layer management. **5B Drawing manipulation** • Typical drawing manipulation commands, including scaling, mirroring, rotating, trimming, moving/translating, corner filleting/chamfering, exploding, copying, arrays/patterns, extending, stretching, erasing.
Learning outcome 6: Know how to produce 2D and 3D industry standard engineering drawings

6A 2D CAD components parts drawings and assembly drawings
• Basic and advanced features of a CAD system (drawings of component parts that form an assembly drawing to BS8888), including:
  ○ basic drawing commands and editing commands to produce and erase lines, circles, text
  ○ outputting to a printer/plotter device
  ○ appropriate tools to allow accurate geometry definition
  ○ manipulation of views, including zoom and pan options
  ○ saving the drawing data in an appropriate format.
• Modification and manipulation of drawn features, including scaling, revolving/rotating, copying/duplicating and moving.

What needs to be learned

- Dimensioning and hatching.
- Drawing template, typically to include a border, title block, projection, scale, drawing number, title of drawing, material, names of drawing creator and who checks/authorises the drawing.
- Further CAD commands, including erase, stretch, trim, scale; absolute, relative and polar coordinates, features, e.g. type of line, grid, snap, circle, text, hatch, zoom-in, zoom-out.

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

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

Essential resources

For this unit, centres will need:

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

Assessment

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

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

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

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

Learning outcome 1

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

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

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

Learning outcomes 2 and 3

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

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

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

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

Learning outcomes 4 and 5

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

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

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

Learning outcomes 6

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

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

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

Unit 13: Grinding Techniques

Level: 2

Unit type: Optional

Guided learning hours: 50

Unit introduction

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

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

Learning outcomes and assessment criteria

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

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

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

Unit content

What needs to be learned
Learning outcome 1: Understand how to use grinding machines safely
1A Health and safety requirements associated with grinding operations • Duties of employees under relevant legislation, with respect to the use of machinery and equipment, risk assessment, personal protective equipment (PPE), hazardous substances. • Environmental considerations such as safe/correct disposal of waste and recycling, maintaining the work area in a safe and tidy condition, reporting damage and faults. **1B Safety precautions relating to the setting up and use of a surface grinding machine** • The specific safety precautions relating to the setting up and use of a surface grinding machine, including checking the abrasive wheel is in a safe condition before starting the machine, ensuring that the workpiece is secure and grinding wheels are free from damage and clear of the workpiece before starting the machine. • Safe working practices and procedures to include procedures for start/stopping the surface grinding machine under normal conditions and in an emergency. • Identification of trapping hazards, e.g. between the table and saddle. • Fitting and adjustment of machine guarding. • Mounting work holding equipment and the workpiece safely. • Procedures for checking the emergency mechanisms are working correctly, e.g. emergency stop button, guard interlocks. • Use of dust extraction equipment. • Use of PPE to include safety glasses, apron/overalls, ear protection.
Learning outcome 2: Know the functions of the tooling and equipment used in grinding operations
2A Functions of the component parts of surface grinding machines • Component parts, including the base, column, wheel head, saddle, table, handwheels, cross traverse, table traverse, wheel guard, splash guard. • Functions, e.g. column handwheel, cross traverse, table traverse.

What needs to be learned
2B Functions and operation of the controls of surface grinding machines • Controls found on surface grinding machines, including trip dogs, reversing valve lever, table speed control, cross feed selector, incremental feed rate control, continuous feed rate control, extractor and coolant system, control panel. • Explanation of the operation of controls of surface grinding machines, e.g. trip dogs, reversing valve lever, table-speed control knob, cross feed selector. **2C Types of work holding devices** • Work holding devices that can be used in surface grinding operations, including magnetic chuck or blocks, precision grinding vice, angle plates, vee blocks and clamps, vee block indexing fixture, e.g. Harig Grind-All. **2D Types of operation that can be carried out on a surface grinding machine** • Engineering applications of surface grinding machines, including flat, parallel and square faces, vertical and angular faces, steps and shoulders, slots, profile forms.
Learning outcome 3: Know how to select, mount and use work-holding equipment used for grinding operations
3A Selecting, mounting and aligning work-holding devices • Factors to be considered when selecting a work-holding device for grinding operations, e.g. shape of component to be ground, complexity of grinding operation, size of the component to be mounted, material properties of the component requiring grinding. • Select, safely mount and align suitable work holding devices to a surface grinding machine for given grinding requirements. **3B Methods of protecting finished surfaces from marking or damage** • Surface finish protection methods when securing to work-holding devices, e.g. faces are clean and free from burrs, using strips of softer material to protect finished surfaces.
Learning outcome 4: Understand the types and applications of abrasive wheels used in grinding operations
4A Types and construction of abrasive wheels, materials and properties • Types of abrasive wheels most commonly used on a surface grinder, including types 1, 5 and 7, wheel identification markings. • Types of material used to manufacture abrasive wheels, their mechanical properties and uses, including aluminium oxide and silicon carbide, typical grain/grit sizes, e.g. coarse, medium, fine, very fine, designation of bonding agent strength and density of grain particles.

What needs to be learned
• Importance of choosing the correct wheel grit and bonding strength for cutting efficiency and the material being cut. **4B Reasons for balancing abrasive wheels** • The importance of balancing abrasive wheels (on initial use and at frequent intervals thereafter), including the prevention of damage to the workpiece, the prevention of damage/wear to the machine spindle bearings, catastrophic failure of the wheel. • Balancing an abrasive wheel, including truing the wheel safely before balancing and re-truing afterwards, the use of a grinding wheel balancing stand, sensitive bubble level, mandrel, wheel mount flanges and balancing weights; how to identify the heaviest part of wheel assembly and how to adjust the balancing weights until the assembly remains stationary in any position. **4C Cutting techniques and their effects** • The effects of applying roughing, finishing and trial cuts, including minimising production costs, achieving the required dimensional accuracy, achieving the required surface finish, the effects that roughing and finishing cuts have on wheel life, surface finish and dimensional accuracy. **4D Abrasive wheel terminology** • Definitions of typical abrasive wheel terms used to include peripheral speed (maximum and recommended) table feed, maximum allowable speed, table speed, cutting depth. • Effects of peripheral speed, table feed, table speed and cutting speed on cutting efficiency and surface finish.
Learning outcome 5: Understand quality standards associated with grinding operations
5A Types of standards in use • Requirements of the current standards in use, including British Standards (BS), European Engineering Standards (EN), International Organisation for Standardization (ISO) with consideration to physical standards, international system of units (SI), National Physical Laboratory (NPL), United Kingdom Accreditation Service (UKAS), primary and secondary calibration standards, calibration certificates, standard specifications. • Reasons for and advantages of implementing quality standards in the manufacture of components, including the elimination of waste and material due to unnecessary production of different patterns and sizes of parts for the same purpose, interchangeability of parts, e.g. ease of servicing and production.

What needs to be learned
5B Typical engineering terms used in quality standards for grinding operations • Meaning of typical engineering terms used in standards, including tolerance, limits of size, limits and fits, classes of fit including clearance, transition and interference. **5C Surface finish measurements** • Methods of measuring surface finish, including contact, surface roughness comparator plates (visual and tactile), electronic roughness tester (stylus type), non-contact, microscopic inspection, e.g. optical microscope. • Units of surface finish and their depiction on engineering drawings.
Learning outcome 6: Know how to set up and operate a surface grinding machine
6A Component parts and controls of a surface grinding machine • Safe use of the component parts and controls of a surface grinding machine. • Component parts, including base, column, wheel head, saddle, table, handwheels, cross traverse, table traverse, wheel guard, splash guard, work-holding device. • Controls, including trip dogs, reversing valve lever, feed controls, speed controls, start/stop buttons, emergency stop buttons, main isolators. **6B Setting up a grinding machine for the manufacture of a ground component** • Prepare an operation sequence for the manufacture of a given ground component. • Set up a grinding machine for the manufacture of a ground component. • Start and stop a surface grinding machine and carry out an emergency stop. • Manufacture a ground component to a given specification. • Carry out quality inspections on a manufactured component to ensure compliance with the given specification.

Essential information for tutors and assessors

Essential resources

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

Assessment

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

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

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

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

Learning outcome 1

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

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

Learning outcome 2

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

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

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

Learning outcomes 3 and 6

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

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

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

Learning outcome 4

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

1. define **three** abrasive wheel terms used in grinding operations including peripheral speed (maximum and recommended), and **two** from table feed, maximum allowable speed, table speed, cutting depth (AC4.1)
2. describe the types and construction of abrasive wheels that are typically used within their own engineering organisation giving technical details such as grit size, density and usage (AC 4.2)
3. explain **three** reasons for ensuring abrasive wheels are balanced and describe the procedures that need to be followed to balance an abrasive wheel (AC4.3, 4.4)
4. describe the cutting techniques undertaken during grinding operations and explain the effects that varying these cuts have on the quality of the components produced (AC 4.5, 4.6)
5. explain the effects of peripheral speed, table feed, table speed and cutting speed on cutting efficiency and surface finish, with relevant examples for each (AC4.7).

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

Learning outcome 5

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

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

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

13 Suggested teaching resources

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

Textbooks

Adams J – *Electrical Safety: A Guide to the Causes and Prevention of Electrical Hazards* (Institution of Electrical Engineers, 1994) ISBN 978-0852968062

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

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

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

Bolton W – *Engineering Science* (Routledge, 2015) ISBN 978-1138828933

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

Clarke S, Darbyshire A, Goulden S, Hallgarth C, Watkins N – *BTEC First in Engineering Student Book (Level 2 BTEC First Engineering)* (Pearson Education, 26 June 2013) ISBN 978-1446902431

Evans K – *Programming of CNC Machines* (Industrial Press, 2007) ISBN 978-0831133160

Grimwood T, Scanlon S, Tooley M, Tooley R – *Performing Engineering Operations – Level 2 Student Book plus options (Performing Engineering Operations)* (Heinemann, 14 May 2012) ISBN 978-043507507

Simmons C and Maguire D – *Manual of Engineering Drawing to British and International Standards* (Butterworth-Heinemann, 2012) ISBN 978-0080966526

Smid A – *CNC Programming Handbook* (Industrial Press, 2008) ISBN 978-0831133474

Sullivan M and Shackleford J – *Introduction to Materials Science for Engineers* (Pearson, 2015) ISBN 978-0133826654

Stroud K – *Engineering Mathematics* (Palgrave Macmillan, 2013) ISBN 978-1137031204

Websites

http://www.freecadweb.org/	Website for free CAD software resources (FreeCAD).
http://freecircuitdiagrams4u.blogspot.co.uk	Example circuit diagrams for various devices.
www.freestudy.co.uk	Engineering Council – open learning tutorials.

14 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 enrolling learners onto Pearson qualifications* (Pearson)
- *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, diversity and inclusion policy* (Pearson)
- *Recognition of prior learning policy and process* (Pearson)
- *Guidance for reasonable adjustments 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.

A guide to the special consideration process (JCQ) – available on the Joint Council for Qualifications (JCQ) website, www.jcq.org.uk

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.

15 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:

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- developing effective assignments
- building your team and teamwork skills
- developing learner-centred learning and teaching approaches
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Your Pearson support team

Whether you want to talk to a sector specialist, browse online or submit your query for an individual response, there is someone in our Pearson support team to help you whenever – and however – you need:

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- 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 A

Glossary of terms used in assessment criteria

This is a summary of the key terms used to define the assessment requirements in the units.

Terms	Definition
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.
Demonstrate	Performance or practice evidences the ability to carry out and apply knowledge, understanding and/or skills in a practical situation.
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.
Identify	Shows the main features or purpose of something. Can recognise it and/or name characteristics or facts that relate to it.
Interpret	State the meaning, purpose or qualities of something through the use of images, words or other expressions.
List	Presentation of specific, required information in a structured format. Essentially a recall of learnt information; although this can be quite complex information.

Terms	Definition
Outline	A description setting out the main characteristics or points; write a clear description but without going into too much detail.
Record	Systematically retain or refine information using various media in formats that are appropriate to the task or response to an assignment or brief.
Report	Adhere to protocols, codes and conventions where matters, findings or judgements are set down in an objective way.
Select	Choose the best or most suitable option whether this is of materials, techniques, equipment or processes. The options and choices should be based on specific criteria.
State	Express information in clear and precise terms.

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