Pearson
BTEC Level 3 Diploma in Composites Engineering

Specification

New Apprenticeship Standards –
Specialist Qualification (England only)

First teaching April 2018

Edexcel, BTEC and LCCI qualifications

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1 Introducing BTEC Specialist qualifications for the new Apprenticeship Standards

Overview

The current reforms to apprenticeships in England includes changes that move the design of apprenticeships into the hands of employers. The aim of this is to make apprenticeships more rigorous and responsive to employers' needs. Employer groups, referred to as Trailblazers, now lead on the development of apprenticeships for occupations where they identify the need for apprentices.

Pearson has been working closely with Trailblazer employer groups in the development of different types of assessment programmes and qualifications, to support the delivery of these new apprenticeships.

As work-related qualifications, BTEC Specialist qualifications are well suited to the new apprenticeships. Through close collaboration with Trailblazer employer groups, these BTEC Specialist qualifications are designed to underpin the development of occupational competencies by giving learners the knowledge, understanding and skills relevant to the Apprenticeship Standards.

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 also means that learners are further supported to progress in their career or further study.

Employers, or colleges and training centres working in partnership with employers, can offer these qualifications as long as they have access to appropriate physical and human resources and that the necessary quality-assurance systems are in place.

Sizes of BTEC Specialist qualifications

For all regulated qualifications, Pearson specify a total number of hours that it is estimated 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 will include 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 TQT, rounded to the nearest whole number.

TQT and credit values are assigned after consultation with users of the qualifications.

BTEC Specialist qualifications for the new Apprenticeship Standards 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).

Other size references, such as Extended Diploma, may be used in a suite of qualifications depending on the specific needs of different sectors and Trailblazer employer groups.

2 Qualification summary and key information

Qualification title	**Pearson BTEC Level 3 Diploma in Composites Engineering**
Qualification Number (QN)	603/3186/0
Regulation start date	01/05/2018
Operational start date	01/05/2018
Approved age ranges	16–18 19+ Please note that sector-specific requirements or regulations may prevent learners of a particular age from embarking on this qualification. Please see *Section 7 Access and recruitment*.
Total Qualification Time (TQT)	1574 hours.
Guided Learning Hours (GLH)	710.
Assessment	Internal assessment.
Grading information	The qualification and units are graded Pass/Merit/Distinction.
Entry requirements	No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification. However, it is expected that learners will have achieved grade C or above GCSEs (or equivalent) in English, mathematics and a science or technology-based subject. Centres must also follow the Pearson access and recruitment policy (see *Section 7 Access and recruitment*).
Funding	The Trailblazer Apprenticeship funding rules can be found on the Skills Funding Agency's website at www.gov.uk/guidance/sfa-funding-rules

Centres should use the Qualification Number (QN) when seeking funding for their learners. The qualification title, units and QN will appear on each learner’s certificate. You should tell your learners this when your centre recruits them and registers them with us. Further information about certification is given in our *UK Information Manual*, available on our website.

3 Qualification purpose

Qualification objective

The Pearson BTEC Level 3 Diploma in Composites Engineering is for learners employed as apprentices in the role of composites technician and are working towards gaining their apprenticeship.

A Composites Technician employed in a composites manufacturing environment will find that they are at the heart of cutting-edge technology, using state-of-the-art equipment. They will gain the skills needed to carry out manufacturing processes and practices using these technologies.

A Composites Technician is engaged in a variety of processes in the production and creation of materials and components used in a range of applications, including but not limited to, aeroplanes, cars, boats, turbine blades, oil and gas rigs, bridges, trains and satellites. A Composites Technician gives specialised knowledge and uses skills that support manufacturing programmes and projects. They could be deployed in the areas of design, tooling, moulding, layup, curing, machining, inspection, testing, repair and material production. As the technician grows in competence and expertise, other areas of composites technology such as automated manufacture development, preform technologies, processing technologies, validation and post-processing, may form part of their role and responsibility.

This qualification gives learners the opportunity to:

- develop the technical knowledge required to meet the Composites Technician Apprenticeship Standard
- develop a range of skills and professional attributes that support successful performance in the workplace
- achieve a nationally-recognised Level 3 qualification.

Apprenticeships

The Pearson BTEC Level 3 Diploma in Composites Engineering is a mandatory requirement within the Composites Technician Apprenticeship Standard. Learners must achieve this qualification before progressing to the End-point Assessment.

The published Composites Technician Apprenticeship Standard and Assessment Plan can be found at:

www.instituteforapprenticeships.org/apprenticeship-standards/
composites-technician/

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Progression opportunities

Learners who achieve the Pearson BTEC Level 3 Diploma in Composites Engineering can progress to achieving the full apprenticeship certification, which confirms competency in the role of Composites Technician. In the longer term, learners can progress to more senior or complex job roles such as supervisor, team leader and senior technician. Learners can also apply for Engineering Technician (EngTech) status with The Institute of Materials, Minerals and Mining (IOM3) and/or the Institution of Mechanical Engineers (IMechE) on completing the apprenticeship.

Learners can progress further via a Higher Level Apprenticeship or Foundation Degree in Composites Manufacture, Materials Engineering or Materials Science, this would lead to a full degree where employers think this appropriate and useful.

Alternatively, learners who have achieved the qualification but who have not completed the full apprenticeship requirements, could progress to the role of Composites Technician after a period of on-the-job training and study or they could progress to other roles in the engineering sector. Completion of this qualification could also lead to further qualifications at Levels 4–6, including degree programmes in an engineering discipline.

Industry support and recognition

The Pearson BTEC Level 3 Diploma in Composites Engineering was developed through close collaboration with the Composites Engineering Trailblazer employer group and professional bodies.

This qualification is supported by the following:

- The Composite Engineering Trailblazer group which consists of a wide range of employers from different sectors
- The Science, Engineering, Manufacturing and Technologies Alliance (Semta) sector skills council.

4 Qualification structure

Pearson BTEC Level 3 Diploma in Composites Engineering

Learners will need to meet the requirements outlined in the table below before the qualification can be awarded.

Minimum number of units that must be achieved	11
Minimum number of units that must be achieved at Level 3 or above	10
Number of mandatory units that must be achieved	9
Number of optional units that must be achieved	2
Number of GLH that must be achieved	710

Unit number	Mandatory units	Level	Guided learning hours
1	Health and Safety in the Engineering Workplace	3	60
2	Engineering Drawing for Technicians	3	60
3	Principles of Working Effectively and Efficiently within Composites Engineering	3	60
4	Business Improvement Techniques	2	50
5	Composite Materials	3	60
6	Composites Manufacturing Processes	3	60
7	Composites Engineering Product Design and Manufacture	3	60
8	Defects, Detection and Repair Processes in Composites Mouldings	3	60
9	Composites Engineering Project	3	120
Unit number	**Optional units**	**Level**	**Guided learning hours**
10	Making Composite Parts Using Prepreg Materials	3	60
11	Wet Layup Techniques	3	60
12	Making Composite Parts Using Resin Infusion Techniques (VRTM and RTM)	3	60
13	Mathematics for Engineering Technicians	3	60
14	Mechanical Principles of Engineering Systems	3	60
15	Computer-aided Drafting in Engineering	3	60
16	Applications of Computer Numerical Control in Engineering	3	60

5 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 this 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 *Collaborative and consortium arrangements for the delivery of vocational qualifications policy* is available on our website.

Those planning the programme should aim to involve employers as far as possible in the delivery of the qualification. This could be through:

- 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 qualification
- 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
- developing up-to-date and relevant teaching materials that make use of scenarios relevant to the sector and relevant occupation
- using 'expert witness' reports from employers to support assessment
- making full use of the variety of experience of work and life that employers bring to the programme.

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

For further information on the delivery and assessment of the new apprenticeships please refer to the SFA funding rules at:
www.gov.uk/government/collections/sfa-funding-rules

Delivery guidance for Pearson BTEC Level 3 Diploma in Composites Engineering

The following delivery guidance is not intended to be prescriptive. Those delivering the learning programme can adapt the guidance to meet the needs of learners, employers and the specific context.

It is important that centres develop an approach to teaching and learning that supports the vocational nature of Pearson BTEC Level 3 qualifications and the mode of delivery. This specification gives a balance of practical skill development and knowledge requirements, some of which can be theoretical in nature.

This specification can be delivered to be biased to a specific sector but it is essential that learners are made aware of how composites are used and applied across a range of sectors. Tutors and assessors need to ensure that appropriate links are made between theory and practical application and that the knowledge base is applied to the sector. This requires the development of relevant and up-to-date teaching materials that allow learners to apply their learning to actual events and activities in the sector. Maximum use should be made of learners' experience.

So that learners experience variations in applications of composites and are able to visualise different business models in action, centres should make links with local composite companies. Learners will need support from the organisations they work for in terms of project topics and investigation of effective team behaviours.

6 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 delivery and assessment process must have relevant expertise and occupational experience. Existing competency must have been acquired during the previous 36 months and cover the units being delivered.
- Staff competency can be developed by:
  - attending training courses covering the units being delivered – information on suitable training programmes can be found on the National Composites Centre website (nccuk.com/training) and the Composites UK website (compositesuk.co.uk/events)
  - undertaking work experience in a composites manufacturing organisation, appropriate for the content of the units that are being delivered.
- Further support can be provided through composite industry experts and experienced composites manufacturers delivering workshops, setting assignments etc.
- There must be systems in place that ensure continuing professional development (CPD) for staff delivering and assessing the qualification.
- Centres must have appropriate health and safety policies in place that relate to learners' use of equipment.
- Centres must have in place robust internal verification systems and procedures in place 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 Quality Assurance Handbook* on our website.
- Centres must deliver the qualification in accordance with current equality legislation. For further details on Pearson's commitment to the Equality Act 2010, please see *Section 7 Access and recruitment.* For full details of the Equality Act 2010, please go to www.legislation.gov.uk

Specific resource requirements

As well as the general resource requirements given above, there are specific resources that centres must provide. They are listed by unit below.

Unit	**Resources required**
Unit 1: Health and Safety in the Engineering Workplace	None required.
Unit 2: Interpret and Create Engineering Drawings	Access to CAD software.
Unit 3: Principles of Working Effectively and Efficiently within Composites Engineering	Case studies outlining the operations of composite engineering organisations. Engineering drawings and other manufacturing data applicable to engineering planning.
Unit 4: Business Improvement Techniques	Internet access. Case studies on business improvement techniques.
Unit 5: Composite Materials	Mechanical test equipment (such as a tensile test machine). Facility for manufacturing composite components. Composite materials and mould tools.
Unit 6: Composites Manufacturing Processes	Facilities or access to facilities that manufacture, trim and assemble composite components. Composite materials and mould tools. Access to a local composite company.
Unit 7: Composites Engineering Product Design and Manufacture	Access to CAD software. Access to national and international engineering standards.
Unit 8: Defects, Detection and Repair Processes in Composites Mouldings	Facilities or access to facilities to carry out composite manufacture and repairs. Ideally, access to non-destructive testing (NDT) equipment.
Unit 9: Composites Engineering Project	Facilities or access to facilities for manufacturing composite components. Ideally, access to NDT equipment. Composite materials and mould tools.

Unit	Resources required
Unit 10: Making Composite Parts using Prepreg Materials	Facilities or access to facilities for manufacturing prepreg composite components. Prepreg composite materials. Mould tools for prepreg components.
Unit 11: Wet Layup Techniques	Facilities or access to facilities for manufacturing wet lay composite components. Wet lay composite materials. Mould tools for wet lay components.
Unit 12: Making Composite Parts using Resin Infusion Techniques (VRTM and RTM)	Facilities or access to facilities for manufacturing resin infusion composite components. Resin infusion composite materials. Mould tools for infusion components.
Unit 13: Mathematics for Engineering Technicians	Electronic scientific calculator. Access to software packages that support understanding of the principles and their application to engineering.
Unit 14: Mechanical Principles of Engineering Systems	Access to laboratory facilities with a sufficient range of investigation and demonstration equipment wherever possible. In particular, tensile testing equipment, dynamics trolleys, linear expansion apparatus, apparatus to determine density
Unit 15: Computer-aided Drafting in Engineering	Access to a suitably equipped IT facility, with access to a printer/plotter. Access to software with 2D and 3D capabilities, such as AutoCAD and Autodesk Inventor is also required. While general graphics packages would not be suitable, any CAD software capable of generating the evidence required for this unit would be acceptable.

7 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.

All learners undertaking an Apprenticeship Standard must be employed as an apprentice and have an Apprenticeship Agreement at the start of the first day of their apprenticeship programme.

Prior knowledge, skills and understanding

No prior knowledge, understanding, skills or qualifications are required before learners register for this qualification. However, it is expected that learners will have achieved grade C or above GCSEs (or equivalent) in English, mathematics and a science or technology-based subject.

Centres must also follow the Pearson Access and Recruitment policy.

Access to qualifications for learners with disabilities or specific needs

Equality and fairness are central to our work. Pearson's *Equality and diversity 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 the information regarding reasonable adjustments and special consideration in *Section 8 Assessment*.

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 all 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.

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

Internal assessment

All units in this qualification 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 qualification before conducting assessments. *Section 9 Centre recognition and approval* gives information on approval for offering this qualification.

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 types. 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 to measure 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. Centres need to ensure that the generation of evidence is carefully monitored and controlled and that it is produced to an appropriate timescale. This helps to make sure that learners are achieving to the best of their ability and that at the same time the evidence is genuinely their own.

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 these 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.
- An outcome must always be assessed as a whole and must not be split into two or more assignments.
- The assignment must be targeted to the learning outcomes but the learning outcomes and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.
- Centres do not have to follow the order of the outcomes of a unit in developing assignments, but later learning outcomes often require learners to apply the content of earlier learning outcomes and they may require learners to draw their learning together.
- Assignments must be structured to allow learners to demonstrate the full range of achievement at all grade levels. Learners need to be treated fairly by being given the opportunity to achieve a higher grade if they have the ability.
- As assignments provide a final assessment, they will draw on the specified range of teaching content for the learning outcomes. The specified content is compulsory. 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 one practical performance, or an investigation of one 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 motivates learners to provide appropriate evidence of what they have learned through providing challenging and realistic tasks. 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
- an explanation of how the assignment relates to the unit(s) being assessed.

Forms of evidence

Centres may use a variety of forms of evidence, provided that they are suited to the type of learning outcome being assessed. For many units, the practical demonstration of skills is necessary, and for others learners will need to carry out their own research and analysis. 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 main forms of evidence include:

- written tasks or reports
- projects
- time-constrained simulated activities with observation records and supporting evidence
- observation and recordings of performance in the workplace
- sketchbooks, work logbooks, reflective journals
- presentations with assessor questioning.

The form(s) of evidence selected must:

- allow the learner to provide all the evidence required for the learning outcome(s) and the associated assessment criteria at all grade levels
- 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 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 Quality Assurance Handbook* on our website.

Making valid assessment decisions

Authenticity of learner work

Once an assessment has begun, learners must not be given feedback on progress towards fulfilling the targeted criteria.

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 the assessment period. Assessors must take care not to provide direct input, instructions or specific feedback that may compromise authenticity.

Assessors must complete a declaration that:

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

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

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

Making assessment decisions using unit-based criteria

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

Assessors make judgements using the criteria and must show how they have reached their decisions in the assessment records. The evidence from a learner can be judged using all the relevant criteria at the same time. 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 assessment* section of each unit, which gives examples and definitions related to terms used in 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, the assessment team will give an assessment outcome for the unit. This is given according to the highest level for which the learner is judged to have met all the criteria. Therefore:

- to achieve a Distinction, a learner must have satisfied all the Distinction criteria (and therefore the Pass and Merit criteria); these define outstanding performance across the unit as a whole
- to achieve a Merit, a learner must have satisfied all the Merit criteria (and therefore the Pass criteria) through high performance in each learning aim
- to achieve a Pass, a learner must have satisfied all the Pass criteria for the learning outcomes, showing 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 Pass criteria 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 assessment team 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 *Supplementary guidance for reasonable adjustments and special consideration in vocational internally assessed units* (available on our website). In most instances, adjustments can be achieved by following the guidance, for example allowing the use of assistive technology or adjusting the format of the evidence. We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. Any reasonable adjustment must reflect the normal learning or working practice of a learner in a centre or a learner working in the occupational area.

Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document *Adjustments for candidates with disabilities and learning difficulties, 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 *Supplementary guidance for reasonable adjustments and special consideration in vocational internally assessed units*. Special consideration may not be applicable in instances where:

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

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

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

Further information on special consideration can be found in the Joint Council for Qualifications (JCQ) document *Adjustments for candidates with disabilities and learning difficulties, Access Arrangements and Reasonable Adjustments*. Both of the documents mentioned above are on our website.

Appeals against assessment

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

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

Administrative arrangements for external assessment

Access arrangements requests

Access arrangements are agreed with Pearson before an assessment. They allow learners with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

Access arrangements should always be processed at the time of registration.

Learners will then know what type of arrangements are available and in place for them.

Granting reasonable adjustments

For external assessment, a reasonable adjustment is one that Pearson agrees to make for an individual learner. A reasonable adjustment is defined for the individual learner and informed by the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, including:

- the needs of the learner with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the learner with the disability and other learners.

Adjustment may be judged unreasonable and not approved if it involves unreasonable costs, timeframes or affects the integrity of the assessment.

Special consideration requests

Special consideration is an adjustment made to a learner's mark or grade after an external assessment to reflect temporary injury, illness or other indisposition at the time of the assessment. An adjustment is made only if the impact on the learner is such that it is reasonably likely to have had a material effect on that learner being able to demonstrate attainment in the assessment.

Centres are required to notify us promptly of any learners that they believe have been adversely affected and request that we give special consideration. Further information can be found in the special requirements section on our website.

Conducting external assessments

Centres must make arrangement for the secure delivery of external assessments. All centres offering external assessments must comply with the Joint Council for Qualifications (JCQ) document *Instructions for conducting examinations (ICE)*. The current version of this document is 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 actions (or attempted actions) of malpractice by learners, centre staff or centres in connection with Pearson qualifications. Pearson may impose penalties and/or sanctions on learners, centre staff or centres where incidents (or attempted incidents) of malpractice have been proven.

Malpractice may arise or be suspected in relation to any unit or type of assessment within the qualification. For further details on malpractice and advice on preventing malpractice by learners, please see the *Centre Guidance: Dealing with Malpractice* document, available on our website.

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

Internal assessment

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

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

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

Learner malpractice

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

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

Teacher/centre malpractice

The head of centre is required to inform Pearson's Investigations Team of any incident of suspected malpractice by centre staff, before any investigation is undertaken. The head of centre is requested to inform the Investigations Team by submitting a *JCQ Form M2(a)* (available at www.jcq.org.uk/exams-office/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 (accidental errors in the delivery of Pearson qualifications that may affect the assessment of learners) should also be reported to the Investigations Team using the same method.

Heads of centres/principals/chief executive officers or their nominees are required to inform learners and centre staff suspected of malpractice of their responsibilities and rights, please see section *6.15* of the *JCQ Suspected Malpractice in Examinations and Assessments Policies and Procedures* document.

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

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

Sanctions and appeals

Where malpractice is proven, we may impose sanctions or penalties.

Where learner malpractice is evidenced, penalties may be imposed such as:

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

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

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

The centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from the head of centre (on behalf of learners and/or members or staff) and from individual members (in respect of a decision taken against them personally). Further information on appeals can be found in our *Enquiries and appeals about Pearson vocational qualification 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 Centre recognition and approval

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

Centres that have not previously offered BTEC Specialist qualifications need to apply for and be granted centre recognition and approval to offer individual qualifications.

Existing Pearson centres seeking approval to offer BTEC Specialist qualifications for the New Apprenticeship Standards, will be required to submit supplementary evidence for approval, aligned with the associated new standards and assessment requirements.

Guidance on seeking approval to deliver BTEC qualifications is available 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.

10 Quality assurance

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

Centres are required to declare their commitment to ensuring quality and to giving learners 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. Centres offering BTEC Specialist qualifications as part of the New Apprenticeship Standards will receive at least one visit from our Standards Verifier, followed by ongoing support and development. This may result in more visits or remote support, as required to complete standards verification. The exact frequency and duration of Standards Verifier visits/remote sampling will reflect the level of risk associated with a programme, taking account of the:

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

If a centre is offering a BTEC Specialist qualification alongside other qualifications related to the same Apprenticeship Standard, wherever possible, we will allocate the same Standards Verifier for both qualifications.

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

11 Understanding the qualification grading

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

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

Awarding and reporting for the qualification

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

Units are assessed using a grading scale of Distinction, Merit, Pass and Unclassified. All mandatory and optional units contribute proportionately to the overall qualification grade. For example, a unit of 120 GLH will contribute double that of a 60-GLH unit. There is no unit grade of D*.

Qualifications in the suite are graded using a scale of P to D.

Eligibility for an award

To achieve any qualification grade learners must:

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

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

Calculation of the qualification grade

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

Points thresholds

U	0
Pass	71
Merit	112
Distinction	224

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

Points available for internal units

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

	Unit size		
	50 GLH	**60 GLH**	**120 GLH**
U	0	0	0
Pass	5	6	12
Merit	10	12	24
Distinction	20	24	48

Claiming the qualification grade

Subject to eligibility, Pearson will automatically calculate the qualification grade for learners when the internal unit grades are submitted and the qualification claim is made. Learners will be awarded qualification grades for achieving a sufficient number of points in the ranges shown in the table under the *Calculation of qualification grade* heading on the previous page.

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

Examples of grade calculations

Example 1: Achievement of a Diploma with a Pass grade

	GL	Grade	Points
Unit 1	60	Pass	6
Unit 2	60	Pass	6
Unit 3	60	Pass	6
Unit 4	50	Pass	5
Unit 5	60	Pass	6
Unit 6	60	Pass	6
Unit 7	60	Pass	6
Unit 8	60	Pass	6
Unit 9	120	Pass	12
Unit 10	60	Pass	6
Unit 12	60	Pass	6
Totals	**710**	**Pass**	**71**

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Example 2: Achievement of a Diploma with a Merit grade

	GL	Grade	Points
Unit 1	60	Merit	12
Unit 2	60	Merit	12
Unit 3	60	Merit	12
Unit 4	50	Merit	10
Unit 5	60	Merit	12
Unit 6	60	Merit	12
Unit 7	60	Merit	12
Unit 8	60	Pass	6
Unit 9	120	Pass	12
Unit 13	60	Pass	6
Unit 14	60	Pass	6
Totals	**710**	**Merit**	**112**

Example 3: Achievement of a Diploma with a Distinction grade

	GL	Grade	Points
Unit 1	60	Distinction	24
Unit 2	60	Distinction	24
Unit 3	60	Distinction	24
Unit 4	50	Distinction	20
Unit 5	60	Distinction	24
Unit 6	60	Distinction	24
Unit 7	60	Distinction	24
Unit 8	60	Merit	12
Unit 9	120	Merit	24
Unit 12	60	Merit	12
Unit 13	60	Merit	12
Totals	**710**	**Distinction**	**224**

12 Units

Each unit in the specification is set out in a similar way. All units are internally assessed units and follow the same unit format.

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.

Internal units

Section	Explanation
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 the qualification 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 information in *Section 4 Qualification structure* for full details.
Assessment type	This says how the unit is assessed, i.e. whether it is internal or external. See information in *Section 8 Assessment* for details.
GLH	This indicates the number of hours of activities that directly or immediately involve tutors and assessors in teaching, supervising, and invigilating learners. Units may vary in size.
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	These help to define the scope, style and depth of learning of the unit.
Content	This section sets out the required teaching content of the unit. Content is compulsory except when shown as 'e.g.'. Learners should be asked to complete summative assessment only after the teaching content for the unit or learning outcomes has been covered.

Section	Explanation
Assessment criteria	Assessment criteria specify the standard required by the learner to achieve each learning outcome. Each learning outcome has Pass and Merit criteria. Distinction criteria represent outstanding performance in the unit.
Further information for teachers and assessors	This section gives information to support the implementation of assessment. It is important that the information is used carefully, alongside the assessment criteria.
Resource requirements	This section lists any specific resources that are needed to be able to teach and assess the unit.
Essential information for assessment	This gives guidance on the expectations for Pass, Merit and Distinction standard for each learning outcome or assignment. This section contains examples and essential clarification.

Unit 1: Health and Safety in the Engineering Workplace

Level: 3

Unit type: Mandatory

Assessment type: Internal

Guided learning hours: 60

Unit introduction

The welfare of people working or operating in any manufacturing or engineering environment is of prime importance. All workers should be able to carry out their work in a safe manner that has no negative effect on their health and wellbeing. In fact, many organisations not only reduce risks and make improvements to the working environment, but try to make their own working environment superior to others, making it a competitive aspect when recruiting staff.

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

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

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

This unit could form a key component in many learning programmes since the content is highly applicable to many manufacturing, engineering and industrial situations.

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

Learning outcomes

In this unit you will:

1 Understand health and safety legislation and regulations

2 Know about hazards and risks in the workplace

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

Content

What needs to be learned
Learning outcome 1: Understand health and safety legislation and regulations
Key features of legislation and regulations: the general contents of legislation and regulations or other relevant international equivalents and how they are satisfied by safe systems of work/procedures, including: o Health and Safety at Work etc. Act 1974 – duties of employers, employees, Health and Safety Executive (HSE) and others, general prohibitions o Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013 (as amended) – duties of employers, self-employed and people in control of work premises (the Responsible Person) to report certain serious workplace accidents, occupational diseases and specified dangerous occurrences o Personal Protective Equipment (PPE) at Work Regulations 1992 (as amended) – appropriate if risk cannot be controlled in any other way, types, assessing suitable PPE given the hazard, supply, instructions/training, correct use, maintenance and storage o Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended) – identifying harmful substances, assessing risks of exposure, types of exposure, safety data sheets, using/checking/maintaining control measures/equipment, training/instruction/information o Manual Handling Operations Regulations (MHOR) 1992 (as amended) – avoid the need for manual handling, types of hazard, assess risk of injury when manual handling is required, control and reduce the risk of injury, training in use of techniques/mechanical aids o Environmental legislation and EU directives: Environmental Protection Act 1990; Pollution Prevention and Control Act 1999; Clean Air Act 1993; Radioactive Substances Act 1993; Controlled Waste Regulations 2012; Controls on Dangerous Substances and Preparations Regulations 2006 *Roles and responsibilities of those involved*: employers; employees; HSE, e.g. span of authority, right of inspection, guidance notes and booklets; others, e.g. management, subcontractors, public, suppliers, customers, visitors *Application of environmental management systems*: ISO 14000 (family of standards, a management tool); environmental management (what an organisation does to minimise the harmful effects on the environment caused by its activities); ISO 14004 (guidelines on the elements of an environmental management system and its implementation, and examines principle issues involved); ISO 14001 (specifies the requirements for such an environmental management system)

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

Learning outcome 3: Understand the methods used when reporting and recording accidents and incidents
Principles: why employers keep records of serious accidents, incidents and emergencies; responsibilities of competent persons; cost of accidents, e.g. direct, indirect, human consequences; trends, e.g. major causes, fatal and serious injury, methods of classification, statistics *Recording and reporting procedures*: regulations on accident recording and reporting, e.g. RIDDOR 1995, accident book, company procedures; procedures to deal with near misses or dangerous occurrences

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Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P1 Explain the key features of relevant regulations on health and safety as applied to a working environment in two selected or given engineering organisations	M1 Explain the consequences of management not abiding by legislation and regulations when carrying out their roles and responsibilities in a given health and safety situation	D1 Assess the extent to which legislation and regulations are satisfied in a given health and safety situation
P2 Describe the roles and responsibilities, under current health and safety legislation, and regulations of those involved in two selected or given engineering organisations		
P3 Explain the key features of the relevant legislation and EU directives, with regard to environmental management	M2 Explain the consequences of management not abiding by environmental management legislation and regulations when carrying out their roles and responsibilities	
P4 Explain the requirements for the safe disposal of waste		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P5 Describe the methods used to identify hazards in a working environment	M3 Explain how hazards that become risks can be controlled	D2 Justify the methods used to deal with hazards in accordance with workplace policies and legal requirements
P6 Carry out a risk assessment on a typical item/area of the working environment	M4 Explain the importance of carrying out all parts of a risk assessment in a suitable manner	
P7 Suggest suitable control measures after a risk assessment has been carried out and state the reasons why they are suitable		
P8 Suggest a suitable process or equipment to assist in moving different loads correctly and safely		
P9 Describe the precautions needed for the safe storage of gases, oil, acids, adhesives and engineering materials		
P10 Explain the principles that underpin reporting and recording accidents and incidents		
P11 Describe the procedures used to record and report accidents, dangerous occurrences or near misses.	M5 Explain how control measures are used to prevent accidents.	D3 Assess the potential costs and implications for the organisation and the individual as a result of an accident in the workplace.

Further information for tutors and assessors

Resources

Learners will require access to a wide range of safety literature. Ideally, the centre will be able to provide access to health and safety legislation and learning materials on DVD.

Suggested reading

Textbooks

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

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

Health and Safety Executive – *Essentials of Health and Safety at Work* (HSE Books, 2006) ISBN 9780717661794

Health and Safety Executive – *Management of Health and Safety at Work* (HSE Books, 2000) ISBN 9780717624881

Health and Safety Executive – *Health and Safety in Engineering Workshops* (HSE Books, 2004) ISBN 9780717617173

Websites	
www.hse.gov.uk	HSE

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, M2, D1	Health and Safety Legislation and Regulations	A written activity requiring learners to explain the key features of relevant legislation and regulations and describe the roles and responsibilities of management and the personnel involved.	A report containing written responses about the key features, responsibilities and management of health and safety legislation and regulations set in a relevant context for learners.
P4, P5, P6, P7, P8, P9, M3, M4, D2	Controlling Hazards and Risks in the Workplace	A practical activity to carry out a risk assessment, plus a written report and oral questioning.	A report, carried out under controlled conditions, describing the methods used to identify hazards and how hazards become risks. A written risk assessment of a typical working environment. A report with written responses that identify control measures and their justification. A record of observation by the tutor of the learner's practical risk assessment.
P10, P11, M5, D3	Reporting and Recording Accidents and Incidents	A written activity requiring learners to explain principles of reporting accidents, incidents and near misses.	A report, carried out under controlled conditions, explaining reporting accidents, incidents and near misses.

Assessment

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

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

To achieve a pass, learners must demonstrate an understanding of health, safety and welfare issues as applied to engineering processes and companies. They will need to explain the key features of legislation and regulations and describe a range of roles and responsibilities. They will understand the connection between hazard identification, risk assessment and accident prevention. Learners will carry out a risk assessment, suggest suitable controls and show they understand the principles and procedures for reporting and recording accidents and other occurrences relative to health and safety.

This unit could be assessed through three assignments. The first assignment could have a series of written tasks. The first task could ask learners to research and then explain the key features of relevant regulations as applied to two separate working environments (P1). It would be expected that at least four regulations should be considered across the two selected or given engineering organisations.

Another task could require them to describe the roles and responsibilities of those involved in the environments selected above (P2). The organisations selected could include learners' places of work, or a training workshop or machine shop environment. A combination of one electrical and one mechanical type would be most appropriate. The assignment should cover legislation and regulations. It is not expected that all the legislation and regulations listed in the content would be covered, just those applicable to the given context.

The roles and responsibilities of those involved could include employers, employees, the HSE and any one from the list of others in the unit content. A further task could then be used, asking learners to explain the consequences of management not abiding by legislation and regulations when carrying out their roles and responsibilities in one of these situations (M1). For the same situation, learners could carry out research to assess how the legislation and regulations are satisfied (D1). They might consider reviewing workplace incident/accident records/reports.

P3 and M2 could be achieved using a similar approach and applying this to environmental management. All responses could be in a written format, although for the pass criteria a presentation to the class or annotated poster could be used. In these cases it must be remembered that the presentation skills or poster design skills are not being assessed.

The second assignment could cover P4 to P9, along with the higher criteria M3, M4 and D2. The whole assignment could be based on a practical activity to produce a risk assessment on a typical item or area of a working environment. Again, this working environment could be learners' workplace or one from the centre's own workshops. Whichever item or area is chosen, it should have a range of hazards that can be identified, for example a machining operation or electrical assembly/wiring type activity could be used.

Written tasks would have to be set to give learners opportunities to achieve the explanations required for P4 to P9, M3 and M4, and the justification required for D2. P7 could be achieved through an oral question and answer session after carrying out the risk assessment. A standard template can be used to capture the outcomes of the risk assessment as this is what would be found in normal company use. A witness statement/observation record could be used to show learner performance against the requirement of P6.

The final assignment could cover the remaining criteria P10, P11, M5 and D3, with a written task given for each. Learners should be given opportunities to investigate trends in an area they are interested in, which again may be an area similar to their workplace. The assignment should include a range of data given to each learner, some of which may have been researched and collected during the delivery of this part of the unit content.

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Unit 2: Engineering Drawing for Technicians

Level:	**3**
Unit type:	**Mandatory**
Assessment type:	**Internal**
Guided learning hours:	**60**

Unit introduction

The welfare of people working or operating in any manufacturing or engineering environment is of prime importance. All workers should be able to carry out their work in a safe manner that has no negative effect on their health and wellbeing. In fact, many organisations not only reduce risks and make improvements to the working environment, but try to make their own working environment superior to others, making it a competitive aspect when recruiting staff.

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

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

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

This unit could form a key component in many learning programmes since the content is highly applicable to many manufacturing, engineering and industrial situations.

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

Learning outcomes

In this unit you will:

1 Be able to sketch engineering components

2 Be able to interpret engineering drawings that comply with drawing standards

3 Be able to produce engineering drawings

4 Be able to produce engineering drawings using a computer-aided design (CAD) system.

Content

What needs to be learned
Learning outcome 1: Be able to sketch engineering components
Sketches: regular solids, e.g. cube, rectangular block, 900 angle bracket; hollow objects, e.g. circular tube, square section tube; standard components, e.g. nuts, bolts, screws, pulleys; engineering components, e.g. pulley support bracket, machine vice *Sketching techniques*: sketching equipment, e.g. paper (plain, squared, isometric), pencil, eraser; pictorial, e.g. oblique drawing (cavalier and cabinet), isometric; orthographic, e.g. single and linked views; sketching in good proportion; dimensions, e.g. overall sizes, detail *Benefits and limitations of using pictorial techniques*: benefits, e.g. speed of production, visual impact; limitations, e.g. lengths and shapes not true, not produced to a recognised standard, dimensions difficult to read; consequences of interpretation errors, e.g. incorrect manufacture, incorrect assembly, cost to scrap
Learning outcome 2: Be able to interpret engineering drawings that comply with drawing standards
Interpret: obtaining information from engineering drawings, e.g. component features, dimensions and tolerances, surface finish, manufacturing detail, assembly instructions, parts list, circuit operation *Drawing standards*: British Standards, e.g. BS 8888, BS 3939, BS 2917, PP 7307; company-standardised layouts, e.g. drawing number, title and issue number, projection symbols (first angle, third angle), scale, units, general tolerances, name of person responsible for producing drawing; line types, e.g. centre, construction, outline, hidden, leader, dimension; lettering, e.g. titles, notes; orthographic projection, e.g. first angle, third angle; views, e.g. elevation, plan, end, section, auxiliary; representation of common features, e.g. screw threads, springs, splines, repeated items; section views, e.g. hatching style, webs, nuts, bolts and pins, solid shafts; symbols and abbreviations, e.g. A/F, CHAM, Φ, R, PCD, M; circuit symbols, e.g. electrical, electronic, hydraulic, pneumatic
Learning outcome 3: Be able to produce engineering drawings
Detail drawings of single-piece engineering components: projection method; scale; title block; line work; views; sections; dimensions; tolerances; surface finish; notes *Assembly drawings*: line work, e.g. centre lines, construction, outline, cutting plane, sectional view, hatching; representation of standard components, e.g. nuts, bolts, screws, keys; parts referencing, e.g. number referencing, parts list; notes, e.g. assembly instructions, installation features, operating instructions *Circuit diagrams*: circuits, e.g. electrical, electronic, hydraulic, pneumatic; components, e.g. transformers, rectifiers, solenoids, resistors, capacitors, diodes, valves, pumps, actuators, cylinders, receivers, compressors

Learning outcome 4: Be able to produce engineering drawings using a computer aided design (CAD) system
Prepare a template: standardised drawing sheet, e.g. border, title block, company logo; save to file *CAD systems*: computer systems, e.g. personal computer, networks; output devices, e.g. printer, plotter; storage, e.g. server, hard disc, CD, pen drive; 2D CAD software packages, e.g. AutoCAD, Microstation, Cattia, Pro/Engineer, Pro/Desktop *Produce engineering drawings*: set-up commands, e.g. extents, grid, snap, layer; drawing commands, e.g. coordinate entry, line, arc, circle, snap, polygon, hatch, text, dimension; editing commands e.g. copy, move, erase, rotate, mirror, trim, extend, chamfer, fillet *Store and present engineering drawings*: save work as an electronic file, e.g. hard drive, server, pen drive, DVD; produce paper copies, e.g. print, plot, scale to fit

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P1 Create sketches of engineering components using a range of techniques	M1 Assess the suitability of the different techniques for the sketches	
P2 Describe the benefits and limitations of using pictorial techniques to represent a given engineering component		
P3 Interpret the main features of a given engineering drawing which complies with drawing standards	M2 Explain in the importance of working to recognised standards when producing engineering drawings	
P4 Produce detailed drawings of three given single-piece components that comply with drawing standards	M3 Explain how the sketches comply with drawing standards	
P5 produce an assembly drawing of a product containing three parts that complies with drawing standards		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P6 Produce a circuit diagram that complies with drawing standards, with at least five different components which use standard symbols	M4 Explain in how a given engineering drawing would be used and the reasons it is suitable for its intended audience M5 Explain the hardware components of a typical industry standard CAD system.	D1 Evaluate the use of different methods of producing engineering drawings including manual and computer aided methods D2 Evaluate the functionality of a CAD software package.
P7 Prepare a template drawing of a standardised A3 sheet using a CAD system and save to file		
P8 Produce, store and present 2D CAD drawings of a given single-piece component and an assembly drawing of a product containing three parts.		

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Further information for tutors and assessors

Resources

To meet the needs of this unit, it is essential that centres have, or have access to, manual drawing equipment and a CAD system that uses a 2D commercial engineering software package. Centres will also need extracts and illustrations from appropriate drawing standards and conventions.

Suggested reading

Textbooks

Cheng R – *Using Pro/Desktop 8* (Delmar, 2004) ISBN 9781401860240

Conforti F – *Inside Microstation* (Delmar, 2005) ISBN 9781418020842

Fane B – *AutoCAD 2014 for Dummies* (John Wiley and Sons, 2013) ISBN 9781118603970

Simmons C, Maguire D and Phelps N – *Manual of Engineering Drawing* (Butterworth-Heinemann, 2009) ISBN 9780750689854

Tooley M and Dingle L – *BTEC National Engineering* (Routledge, 2010) ISBN 9780123822024

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, M1	Producing Engineering Sketches	Learners have been asked to produce sketches of a range of different objects.	A practical assignment requiring learners to produce a portfolio of engineering sketches with accompanying written descriptions.
P3, M2	Interpreting and Using Drawing Standards	Learners have to read and interpret an engineering drawing in order to report the key features of the component, circuit or assembly to a colleague.	A written assignment for which learners need to produce a short report detailing the main features of a given engineering drawing that complies with drawing standards. A further task would require them to explain the importance engineering standards.
P4, P5, M3	Producing Engineering Drawings	Learners need to produce an engineering drawing of three components and an assembly drawing for use by the manufacturing department of their company.	A practical assignment in which learners produce component and assembly drawings.

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Criteria covered	Assignment title	Scenario	Assessment method
P6, M4, D1	Producing Circuit Drawings	Learners need to produce a circuit diagram for use by the manufacturing department of their company.	A practical assignment in which learners produce a circuit diagram.
P7, P8, M5, D2	Producing Engineering Drawings Using CAD	Learners need to prepare and produce 2D CAD drawings for use by the manufacturing department of their company.	A practical assignment in which learners produce 2D CAD drawings of a component and an assembly.

Assessment

Assessment of this unit could be through the use of five assignments. To achieve a pass, learners are expected to show competence in a number of graphical techniques and to be able to apply these to the production of engineering drawings which meet recognised standards.

The first assignment, to cover P1, P2 and M1, could consist of a small portfolio of sketches and written descriptions. Items drawn must include regular solids and hollow objects, standard and engineering components. The techniques used must be valid and involve sketching equipment, pictorial and orthographic representation and sketching in good proportion with the addition of some dimensions (as specified in the unit content). An assessment of these techniques will meet the requirement for M1.

The second assignment, to cover P3 and M2, will need to be carefully structured and should be based on a drawing of a component or assembly rather than a circuit diagram so that the unit content can be properly covered. M2 builds on the evidence presented for P3 and these two criteria could be assessed using a single assignment. The wider issues of standardisation and manufacturing for the global market place should be addressed with learners supporting their explanations with case study evidence.

The third assignment could cover P4, P5 and M3 with the three single-piece components in P4 being used for the assembly drawing in P5. This would then make the assignment more realistic in terms of what happens in industry. M3 would require an explanation of how the sketches in P4 comply with drawing standards.

The fourth assignment could cover P6, M4 and D1, with learners being given a choice of the type of circuit they produce depending on their interest (i.e. from electrical, electronic, hydraulic and pneumatic). The circuit can be drawn by hand but using CAD may be the preferred method if a library of components is available. M4 requires an explanation of the use of engineering drawings to communicate information effectively. D1 could be carried out as a separate task, requiring an evaluation of the various drawing techniques used by learners and link directly with the criteria P1, P5, P6 and P8. To add depth to their evidence, learners could be asked to look more widely at what is used in industry – particularly the use of 3D CAD systems which generate solid models. This would then bring them full circle back to the start of the unit, where they were producing pictorial sketches.

P7, P8, M5 and D2 can be covered by a fifth assignment, which could ask for increased competence in the application of standards when producing drawings. To help authenticate learners' work, additional evidence could be in the form of witness statements, tutor observation records and 'screen dumps' which show the range of commands used during the development of the drawings. M5 and D2 could form a separate task as part of this assignment, requiring an explanation of CAD hardware and an evaluation of CAD software functionality.

Unit 3: Principles of Working Effectively and Efficiently within Composites Engineering

Level:	**3**
Unit type:	**Mandatory**
Assessment type:	**Internal**
Guided learning hours:	**60**

Unit introduction

One of the key drivers for business success in manufacturing organisations is how operations are organised and how they respond to economic, social and technological change. It is vital that appropriate manufacturing systems and processing methods are employed to manufacture products safely, sustainably and cost-effectively.

In this unit, you will develop the knowledge and practical ability to be a more effective team member. Good organisational skills add to the effectiveness of a team, and you will have the opportunity to develop your organisational skills further and show how you can organise your own work effectively and demonstrate good team-working skills.

Providing support for team members is very important for any team to succeed and achieve their goals. This unit will help you to understand the importance of working in and supporting your team, and enables you to contribute to improving the effectiveness of the team and demonstrate effective communication skills.

You will understand the importance of human resource management in terms of building successful teams and the effect this can have on the recruitment and retention of employees. The ability to communicate effectively is an essential skill in all aspects of life. The usual methods of communication – speaking, reading and writing – receive considerable attention and learning time during all stages of education. For engineers, these skills are of no less importance, but they must also be able to convey technical information such as scale, perspective and standards of working.

Learning outcomes

In this unit you will:

1 Understand effective team working and the impact of behaviours on a business and its employees

2 Examine employment rights and how those rights impact on a business and its employees

3 Understand composites manufacturing operations and how manufacturing constraints influence production

4 Explore how engineering organisations use quality systems and value management to create value.

Content

What needs to be learned
Learning outcome 1: Understand effective team working and the impact of behaviours on a business and its employees
Characteristics and benefits of an effective team *Characteristics*: sense of purpose, prioritisation of team goal, members have clear roles, clear lines of authority and decision making, conflict dealt with openly, personal traits appreciated and utilised, group norms set for working together, success shared and celebrated, trained and skilled members, good interpersonal relationships, all have opportunity to contribute. *Benefits*: contribution to the productivity and effectiveness of the business, development of a common purpose, clarification of roles, reduction of alienation, sharing of expertise, identification and development of talent, increased motivation, fostering innovation, stretching people's talents. **Team-building techniques** *Team membership and roles*: team members have the required technical and role-based skills, leadership is established, clear lines of authority. *Belbin's nine team roles*: identification of people's behavioural strengths and weaknesses in the workplace to provide a balanced team, contributions and allowable weaknesses of each role. *Tuckman's four stages of team development*: the link between the relationships in the group and the focus on the task. *Purpose and goal*: purpose is communicated and agreed, all team members working towards a common goal, collaborative decision making, responsibility for tasks. *Communication*: vision/objectives/targets are shared, work proceeds more smoothly and efficiently, cooperation among team members is enhanced, feedback is encouraged, openness and trust are promoted, good work ethics and mutual respect are established, team is led by example, members are encouraged to deal with challenges without complaining, members support and respect each other. *Rewards*: regular positive and supportive feedback, acknowledgement and recognition of team and individual success. **Causes of team conflict** *Importance of group/team dynamics.* *Bell and Hart's eight causes of conflict*: conflicting resources, conflicting work styles, conflicting perceptions, conflicting goals, conflicting pressures, conflicting roles, different personal values, unpredictable policies. *Non-compliance with rules and policies*: personal non-compliance or disregard for company policy by colleagues (discriminatory behaviour, unacceptable language, poor attendance and timekeeping). *Misunderstandings*: poor communication leading to misunderstandings. *Competition/rivalry*: competition instead of collaboration, anti-productive behaviour.

Learning outcome 2: Examine employment rights and how those rights impact on a business and its employees
Basic employment rights available to all employees *Pay*: national minimum wage, illegal deductions, timing of payment. *Holiday entitlement*: full- and part-time employees. *Family*: maternity and paternity leave, unpaid parental leave. *Workplace, e.g.*: rights associated with flexible working, time off for trade union duties, access to a trade union representative in the event of a grievance, weekly and daily rest breaks, not to be harassed or discriminated against, 'whistleblowing', rights to study and training if aged 16–17. *Duties of employer*: provide work, pay, health and safety compliance. *Duties of employee*: obey reasonable instructions/orders, not to steal, comply with health and safety requirements. **Contracts of employment and other documentation** *Types of contract*: full time, part time, temporary, fixed, trainee, zero hours, flexible. *Formation of a contract*: offer, acceptance, consideration, intent; express and implied terms, terms incorporated through custom and practice; commencement of a contract; determining if the employee is employed or self-employed; changes to a contract. *Rules relating to issuing of the written statement, e.g.*: where it can be found if not a single document, timescales for issuing to a new employee, what to do if a written statement is not received. *Contents of the written statement of employment particulars, e.g.*: business name, employee's name, job title and/or job description, start date, if a previous job counts towards service, how much and when the employee will be paid, hours of work and the days/times that work will be undertaken, details relating to overtime, holiday entitlements, location of work. *Other contents, e.g.*: length of temporary employment, end date of fixed contract, notice periods, collective agreements, pension details, processes for dealing with a grievance, how to complain. Access to information or policies on sick pay, disciplinary, grievance and dismissal procedures. Content of a contract of employment, reasons for having a contract of employment versus statement of particulars. **Ensuring equality in employment** Protected characteristics, definition and description (Equality Act 2010), e.g. age, disability, gender reassignment, marriage and civil partnership, pregnancy and maternity, race, religion or belief, sex, sexual orientation – need for employee training to avoid work-based problems. *Prohibited conduct, e.g.*: direct and indirect discrimination, violence, bullying, theft, illegal use of electronic communication, harassment, gambling on the job, verbal and physical abuse, practices relevant to the specific business.

Organisations who can support the rights of the employer and employee
The Advisory, Conciliation and Arbitration Service (Acas), trade unions, Health and Safety Executive (HSE), Citizens Advice, Equality Advisory and Support Service (EASS), law centres, Tribunals Service and Employment Appeal Tribunal (EAT) database, European Court of Human Rights, Confederation of British Industry (CBI).

Learning outcome 3: Understand composites manufacturing operations and how manufacturing constraints influence production
Sectors: primary manufacturing, e.g. aerospace, defence, automotive, renewables, marine, construction, rail, oil and gas. *Engineering functions, e.g.*: research and development (R&D), design, manufacture, materials supply and control, production planning and control, installation, commissioning, maintenance, technical support, project planning and management, quality assurance. *Production considerations*: market requirements; design of product; plant and equipment availability; plant and equipment layout; personnel; production control; quality control; cost; types of production, e.g. volume, flow, automated, batch, one-off. *Methods and application of cellular and just-in-time (JIT) production*: relation to modern production requirements; application of push and pull types of production to meet company and customer needs and expectations. *Production planning*: scheduling, loading, despatching (co-ordination of pre-production activities); requirements, e.g. engineering drawings, technical data, personnel, machinery/tools, components, materials, consumables; process charts, e.g. flow charts/diagrams, Gantt charts; symbols used in process charts. *Environmental constraints, e.g.*: sustainability, environmental impact, use of renewable energy resources, carbon footprint, recycling, product end-of-life strategy, REACH.
Learning outcome 4: Explore how engineering organisations use quality systems and value management to create value
Quality systems Quality standards and accreditation include international quality standards that can be applied for voluntarily by engineering organisations, allowing them to show that they have quality management systems in place. Quality standards associated with engineering activities include: • the International Organization for Standardisation (ISO) 9000 series, a quality assurance system for the manufacturing and service industries, including: ISO 9000 – knowledge of the 20 requirements for a quality management system, ISO 9001 – a planning tool for quality, and to support continual improvement • the ISO 14000 series, an environmental management system, including: ISO 14001 – a method of reducing waste, ISO 14006 – to improve product quality in an environmentally positive way, ISO 14040 series – for life-cycle assessments. *Quality assurance*: definition – planned activities to ensure that the quality requirements of a product or service are met: • quality assurance as a company-wide philosophy • total quality management (TQM) – PDCA cycle (plan, do, check, act).

Purposes of implementing a quality system, including:

- benchmarking against other organisations
- ensuring consistency of processes
- ensuring conformity of the product or service to a standard
- reducing unnecessary waste, e.g. inventory, over processing and overproduction
- improving the effectiveness of the engineering organisation
- gaining a competitive advantage
- achieving customer satisfaction
- ensuring that a product or service is fit for purpose.

Quality control:

- the testing and monitoring of activities that are used to check the quality of a product or service outcome
- inspection, sampling and testing
- condition monitoring, e.g. cure monitoring, non-destructive testing (NDT)
- planned maintenance
- applying a 'right first time' philosophy.

The principles and processes of value management

Principles of value management:

- definitions of cost, value, value-added and non-value added activities
- concepts of function, process and product reasons for poor value, e.g. lack of innovation, poor communication.

Phases in the process of carrying out a value analysis exercise on a product or service:

- information phase, e.g. identification of key issues, identification of value-added and non-value added processes, and cost overviews
- analysis phase, e.g. functional analysis, which existing processing methods are used, identifying features or parts that are unnecessary
- creative phase, e.g. generating alternatives for better-value solutions, problem-solving tools and methods, developing a least-cost solution
- evaluation phase, e.g. assessing and prioritising ideas
- development and reporting phase, e.g. refining ideas and developing action plans.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Understand effective team working and the impact of behaviours on a business and its employees		
P1 Discuss the roles in an existing team at a chosen composites engineering business.	M1 Assess how and why an existing team benefits a chosen composites engineering business.	D1 Evaluate the effectiveness of an existing business team and justify why it benefits a chosen composites engineering business.
P2 Discuss the dynamics of an existing team and how they work towards their goals.		
Learning outcome 2: Examine employment rights and how those rights impact on a business and its employees		
P3 Explain what the written statement of employment particulars and the contract of employment must include to comply with the law.	M2 Analyse the impact of employment rights on employees and the support available from relevant organisations to employees to ensure equality in the workplace.	D2 Evaluate the impact that employment rights in the workplace and the support available from relevant organisations regarding equality legislation have had on businesses.
P4 Explain how compliance with equality issues can help employers and employees.		

Learning outcome 3: Understand composites manufacturing operations and how manufacturing constraints influence production		
P5 Complete a production planning exercise on a given composite structure or component.	M3 Complete a production planning exercise on a given composite structure or component, while documenting alternative solutions, justifying the design decisions and considering scalability.	D3 Optimise the production plan of a given composite structure or component in terms of scalability, efficiency of production and environmental impact.
P6 Explain the purpose of different types of production and the considerations that need to be identified when selecting a production method for a given composite structure or component.		
P7 Explain the environmental constraints that must be taken into consideration when planning the production of a composite structure or component.		
Learning outcome 4: Explore how engineering organisations use quality systems and value management to create value		
P8 Explain the purposes of different quality management systems and value management used by engineering organisations.	M4 Analyse the purpose of different quality management systems and value management used by engineering organisations.	D4 Evaluate the outcome of a value management exercise for a given engineering activity and make recommendations that include the use of quality systems to implement efficiencies in the engineering activity.
P9 Complete a value analysis exercise on a given engineering process.		

Further information for tutors and assessors

Resources

The special resources needed for this unit are:

- case studies outlining the operations of composite engineering organisations
- engineering drawings and other manufacturing data applicable to engineering planning.

Suggested reading

Textbooks

Jacobs F R et al – *Manufacturing Planning and Control for Supply Chain Management* (McGraw-Hill Education, 2011) ISBN 9780071750318

Torrington D et al – *Human Resource Management* (Pearson, 2014) ISBN 9780273786634

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Understand effective team working and the impact of behaviours on a business and its employees	Team working and its impact on a business	A report that examines teams in a composites engineering business setting. It should consider their purpose and the benefits of these teams to the business. It should also examine the effectiveness of the team in the business setting, reflecting on team theories, and make recommendations for improvements to the team.
2 Examine employment rights and how those rights impact on a business and its employees	Employment rights, equality and their impact on businesses	A fully justified report that explains employment rights, duties and documents, and the impact of compliance and non-compliance with employment and equality rights in the workplace on the employer and employee. A presentation applying the basic laws relating to employment and equality and the effect on a given business of non-compliance.

Learning outcome	Assignment title	Recommended assessment approach
3 Understand composites manufacturing operations and how quality procedures influence production	Production methods, planning and environmental impact	A practical production planning activity where learners plan the production of a composite structure or component, taking into account given business data such as production method, head count, machinery, cure times, quality inspection, environmental constraints, etc. A further informal report will explore the types of production methods available and the environmental constraints that must be considered when producing composite components and structures.
4 Explore how engineering organisations use quality systems and value management to create value	Quality management in composites engineering	A research activity to explore quality systems and value management processes. In addition, an applied value analysis exercise to determine if further value can be created from a composites engineering product or service.

Learning outcome 1 – Team working and its impact on a business

For Distinction standard, learners will give examples of the challenges in building an effective team. To support the evaluation, learners will use examples from their chosen business and from other businesses. They will evaluate the performance and leadership of their chosen team, linking relevant theory and including how the team works together.

For Merit standard, learners will demonstrate clear analysis of the range of techniques used to build effective teams. Some of this analysis should be gained from a visit to a chosen composites engineering business or interview. The report will analyse how the roles in a team support the outcomes of the effective team and this should be referenced to theory.

For Pass standard, learners will discuss the roles and dynamics of a team in their chosen business, and how teams are used in a variety of ways. This will include reference to different types of teams. Team-building techniques and the theory of team development will be included in the report.

Learning outcome 2 – Employment rights, equality and their impact on businesses

For Distinction standard, learners will support their evaluations of the impact on both employers and employees with individual and original statements and examples. They will demonstrate a comprehensive use and application of relevant precedent and statutes to justify their arguments and conclusion. The report must be professional, businesslike and suitable for presentation to clients. In the presentation, learners must be prepared to answer audience questions on their presentation and show a firm grasp and understanding of the information presented, at all levels. A detailed observation statement will be provided for each learner.

For Merit standard, learners will demonstrate a considered and comprehensive understanding of all areas of law covered by the assignment and assessment criteria. They will demonstrate good analytical skills while using relevant decided cases and statutes that show the impact of employment rights and equality on businesses.

For Pass standard, learners will show, in both the report and presentation, their understanding of employment rights and documents. The report will contain a clear and detailed explanation of each of the elements and will be written in the learner's own words to convey a clear understanding of laws relating to employment and equality rights.

Learning outcome 3 – Production methods, planning and environmental impact

For Distinction standard, learners will optimise the production plan in terms of scalability of production, production efficiency, and environmental considerations. As part of this process, learners will document alternative production plans and justify planning decisions. For example, learners will produce production plans using flow production and batch production and comment on the merits of each. Overall, the evidence will be easy to read and understand by a third party who may or may not be a production engineer.

For Merit standard, learners will plan the production of a composite structure or component and will consider scalability as part of their plan, while documenting their alternative production plans and justifying planning decisions. An example of this could be a small and growing engineering firm that is contemplating upsizing and scaling its current batch production methodology to flow production to allow for further scalability. Overall, the plan should be reasonable and practical, explanations will be professional and engineering terminology used accurately. Some parts of the evidence may have more emphasis than others, making it more difficult for a third party to understand.

For Pass standard, learners will produce a production plan for a given composite structure or component, covering the production method, equipment availability, personnel, quality control, cost and environmental considerations. Overall, the evidence will be well structured and there will be some use of appropriate technical language, although there may be some inaccuracies in the terms used. Also, some parts of the evidence may be considered in greater depth than others.

Learning outcome 4 – Quality management in composites engineering

For Distinction standard, learners will use evidence to evaluate the outcomes of a value analysis exercise and consider the results alongside the use of quality management systems. They will identify and explain, using evidence, how efficiencies can be made for a given engineering product or service. Learners will evaluate how quality management tools, such as the ISO 9000 and ISO 14000 groups of international standards, can improve a given engineering activity. For example, learners may include how the problem will be defined and the data collected during the planning stage, how a solution will be developed during the implementation stage, comparisons to the original process that will be considered during the checking stage, and recommendations should be made in the acting stage. Learners will use the findings of this activity, in conjunction with the outcomes of a value analysis activity, to evaluate methods of implementing efficiencies for an engineering activity. They will identify where there is scope to improve quality or where meeting aspects of the ISO 9000/14000 standards will bring an improvement to the product or service. Learners will complete a value analysis exercise for the same product or service and present their results covering the appropriate phases of the process. An example would be a simple engineered product where the cost of the product is the amount paid to manufacture it, its value is how much it is worth, value-added activities include machining and processing, and non-value added activities such as transportation or inspection and testing are also included. Learners will include a functional analysis of the processes involved in producing the outcome, for example considering if different materials that offer better value could be used, with the results being used to generate alternatives that would offer better-value solutions. They will use their analysis to identify where waste, such as excessive manufacturing techniques, occurs during the activity, and identify improvements that could be made to the process to improve efficiency and develop a lower-cost alternative solution. Finally, learners will evaluate their findings from the quality management activity and the value analysis task to identify which areas can increase the profitability and efficiency of the process being investigated. They will suggest methods to improve the activity, and prioritise those aspects that will offer the greatest benefit to the organisation. Overall, the evidence will be logically structured and clearly presented. The evaluation will be written using accurate technical language.

For Merit standard, learners will analyse the quality management and value analysis tools that an engineering organisation uses to improve efficiency and gain a competitive advantage. For example, learners will analyse the potential benefits of implementing a quality system for an activity and how this would relate to the quality assurance and control checks that are already applied to the process. Learners will evaluate what may be achieved by gaining ISO 9001 accreditation and continue to analyse the reasons why value management methods, such as value analysis, are applied to the same engineering activities. Learners will complete an accurate value analysis exercise for a given engineered product or service. The major value-added and non-value added activities will be identified, with cost assumptions for each being made. Learners will produce ideas to improve the value of the processes, for example by suggesting the use of standardised components or removing some non-value added features of the product or service. Overall, the value analysis and associated report will be clearly presented and use correct technical language throughout. The value analysis will be accurate, but may omit some minor aspects of the engineering activity.

For Pass standard, learners will explain how an engineering organisation can use quality and value management systems to create a competitive advantage. For example, learners will explain that quality assurance and quality control are used to improve the outcomes of the product or service, and will give the organisation a competitive advantage, as the product or service being provided will then have greater value. Learners will make reference to relevant ISO standards, such as the ISO 9000 group, which offer engineering organisations the potential to improve quality. They will explain that improving the efficiency of the activity will also improve the competitiveness of the organisation by increasing the value of the outcome compared to the initial cost. Learners will complete a value analysis exercise for a given engineered product or service. Most of the key stages of the process will be identified, with costs associated to each activity. There may be some errors, and some non-value added activities may be missed, but overall the analysis will result in the identification of opportunities for a better-value solution.

Unit 4: Business Improvement Techniques

Level: 2

Unit type: Mandatory

Assessment type: Internal

Guided learning hours: 50

Unit introduction

Engineers need knowledge of business improvement techniques to ensure that they are working efficiently and effectively and to support organisations in ensuring they are competitive in a continuously changing business climate.

In this unit, you will gain knowledge of continuous improvement techniques from their application in the workplace. This will include improving quality and safety, reducing waste and cost, and investigating the improvement cycle. You will also gain an understanding of what is meant by workplace organisation, the effects of being unorganised 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.

As a future engineer, you will need an understanding of the role of business improvement techniques in the workplace environment.

Learning outcomes

In this unit you will:

1 Know what is meant by continuous improvement

2 Understand what is meant by workplace organisation

3 Know what is meant by visual management

4 Understand problem-solving techniques.

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Content

What needs to be learned
Learning outcome 1: Know what is meant by continuous improvement
Benefits • 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 **Categories of work** • Value added • Non-value added • Waste **Categories of waste** • Transport • Inventory • Motion • Waiting • Overproduction • Over processing • Defects • Skills/unrecognised people potential
Learning outcome 2: Understand what is meant by workplace organisation
Unorganised work environment effects • Poor quality • Increased costs • Reduced efficiency • Poor delivery times • Poor morale/teamwork • Poor health and safety

Learning outcome 3: Know what is meant by visual management
Good visual management benefits, e.g. • Accurate and relevant • Eye-catching • Simple • Greater ownership **Types of visual management, e.g.** • Shadow boards • PDCA worksheets • Colour coding • Floor footprints • Storyboards • Gauges • Photographs/pictures • Labelling • Lights • Schedule boards • Kanban (pull systems) • Graphs • Management boards • Other area-specific types of visual management
Learning outcome 4: Understand problem-solving techniques
Techniques, 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

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<table>
<tr><th colspan="3">Assessment criteria</th></tr>
<tr><th>Pass
To achieve a Pass grade the evidence must show that the learner is able to:</th><th>Merit
To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:</th><th>Distinction
To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:</th></tr>
<tr><td colspan="3">Learning outcome 1: Know what is meant by continuous improvement</td></tr>
<tr><td>P1 Explain the meaning of continuous improvement</td><td></td><td></td></tr>
<tr><td>P2 Outline the benefits of applying continuous improvement techniques</td><td rowspan="2">M1 Describe the consequences of not following a structured approach when applying continuous improvement</td><td rowspan="2"></td></tr>
<tr><td>P3 Define each stage of the Plan – Do – Check – Act (PDCA) improvement cycle</td></tr>
<tr><td>P4 Define the three categories of work:
• Value added
• Non-value added
• Waste</td><td rowspan="2">M2 Describe the methods used for increasing Value added, Reducing Non-Value added and reducing waste</td><td rowspan="2">D1 Explain the long-term consequences if the three categories of work are not taken into account when carrying out a continuous improvement activity</td></tr>
<tr><td>P5 Define the different categories of waste</td></tr>
</table>

Learning outcome 2: Understand what is meant by workplace organisation		
P6 Explain the meaning of workplace organisation		
P7 Outline the benefits of having an organised working environment	M2 Explain the methods that can be used to improve workplace organisation and the consequences an unorganised work environment may have	D2 Justify the methods for sustaining good workplace organisation
P8 Describe the effect an unorganised work environment may have		
P9 Explain the importance of Standard Operating Procedures (SOPs) within workplace organisation		
Learning outcome 3: Know what is meant by visual management		
P10 Explain the meaning of visual management		
P11 Describe the benefits of applying good visual management	M4 Explain the benefits of using different types of visual management, including examples of which types may suit specific situations	D3 Explain the consequences if visual management is not applied and kept up-to- date
P12 Describe different types of visual management		

<table>
<tr><th colspan="3">Learning outcome 4: Understand problem-solving techniques</th></tr>
<tr><td>P13 Explain what is meant by a problem within a work environment</td><td></td><td></td></tr>
<tr><td>P14 Describe the benefits of solving work related problems</td><td rowspan="3">M5 Explain the benefits of using different techniques for identifying and analysing problems and benefits of methods used to stop problem reoccurrence</td><td></td></tr>
<tr><td>P15 Outline different techniques used for identifying and analysing problems</td><td></td></tr>
<tr><td>P16 Explain the importance of applying the appropriate corrective action and eliminating the root cause of a problem</td><td>D4 Explain the consequences if the root cause of a problem is not found</td></tr>
</table>

Further information for tutors and assessors

Resources

The special resources needed for this unit are:

- internet access
- case studies on business improvement techniques.

Suggested reading

Textbooks

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

Sayer N J and Williams B – *Lean for Dummies* (Wiley & Sons, 2012) ISBN 9781118117569

Swanson A R – *Analysis for Improving Performance* (Berrett-Koeler, 2007) ISBN 9781576753415

Womack J and Jones D – *Lean Thinking, 2nd Edition* (Free Press, 2006) ISBN 9780743249270

Websites

www.Bized.co.uk	Business Education (Learning Zone)
www.balancedscorecard.org/Resources/Articles-White-Papers/The-Deming-Cycle	Deming Cycle
www.theiet.org/resources/	Institute of Engineering and Technology
www.youtube.com/watch?v=AKSMLe-louc	Introduction to BITs
www.mindtools.com/pages/article/newPPM_89.htm	PDCA cycle
www.problem-solving-techniques.com/	Problem-solving techniques
www.sop-standard-operating-procedure.com/	Standard Operating Procedures
www.businessballs.com	Team roles and leadership
www.tes.co.uk/teaching-resources/	TES Business Management
www.thetimes100.co.uk	The Times 100 Case Studies
www.youtube.com/watch?v=eyGIP5o1CoU	Visual management

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Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Know what is meant by continuous improvement 2 Understand what is meant by workplace organisation	Continuous improvement in the workplace organisation	A written report to include case studies, tables, labelled diagrams/charts, Deming cycle.
3 Know what is meant by visual management	Visual management	A written report to include case studies, and tables.
4 Understand problem-solving techniques	Problem-solving techniques	A written report to include case studies, tables, labelled diagrams/bar charts, visual techniques and Gantt charts.

Learning outcomes 1 and 2 – Continuous improvement in the workplace organisation

For Distinction standard, learners will need to give reasons for their conclusions about the possible consequences for an organisation of not taking into account the three categories of work, for example losing competitive edge, reduction in profit margin and loss of valued customers. Learners will need to give valid reasons to support the methods for sustaining good workplace organisation.

For Merit standard, learners will need to use their knowledge of the pass criteria to give the consequences of not following a structured approach, for example not comparing the actual results against defined targets in the checking stage. Learners will give features and information about methods of reducing waste and investigate an organisation's processes, rules and techniques that can be adapted to add value or reduce non added-value. This could be completed by use of a case study and presented in a table. Learners will need to provide clear details of, and reasons for, methods to improve workplace organisation and the possible consequences of an unorganised workplace. This could be presented in a table.

For Pass standard, learners will learners will need to give clear details of and conclusions about the overall process of continuous improvement within an organisation. They will need to outline the relevant features of at least four benefits. Learners will need to scope the meaning of the Plan-Do-Check-Act cycle of continuous improvement. This could be presented as a relevant labelled Deming circle/cycle. They will then need to scope the meaning of the three categories of work and categories of waste. Learners will need to give an example of workplace organisation and detail its overall purpose of providing a product or service, its aims and culture, and the functions of its departments/divisions. This can be presented as a detailed, relevant labelled diagram/chart.

This can be expanded to include the relevant features of working in both an organised and unorganised working environment. For example, working where there is high or poor morale or where there is a good or poor health and safety record, in organised and unorganised environments respectively. Learners will also need to give reasons for the importance of following standard operating procedures (SOPs). For example, producing good quality products, or maintaining health and safety procedures.

Learning outcome 3 – Visual management

For Distinction standard, learners will use their knowledge and understanding, from the pass and merit level criteria of visual management effectively to give valid reasons for the possible consequences when visual management is not applied effectively and kept up to date. This could be completed by the use of a case study.

For Merit standard, learners will need to identify different types of visual management and evidence their benefits, for example the benefit of using floor footprints is that they give directions, provide a safe environment and are suitable where there is a lot of machinery and movement of vehicles in a busy workshop. This could be completed by the use of a valid case study.

For Pass standard, learners will learners need to detail what visual management is, giving a minimum of four reasons as to why applying it can be a benefit to an organisation, e.g. using improved communication techniques to increase efficiency and effectiveness. They must also give the features of a minimum of six different types of visual management.

Learning outcome 4 – Problem-solving techniques

For Distinction standard, learners will use their knowledge and understanding, from the pass and merit criteria, of problem solving effectively to give valid reasons for the possible consequences if the root cause of a problem is not found. This could be completed by the use of a case study.

For Merit standard, learners will need to identify different problem-solving techniques, for example the benefit of using a Gantt chart is that is allows for identification and analysis of where a problem is occurring in the workplace schedule of a project, and its continued use can prevent the problem reoccurring.

For Pass standard, learners will need to provide a reasoned view of what is meant by a problem, giving an example of a workplace problem such as lack of effective communication from directors to senior management. This can be expanded to include relevant features of the benefits of solving work-related problems, and a summary of at least eight different techniques used to identify and solve workplace problems. Learners will need to give valid reasons for the importance of taking corrective action and removing the root cause of problems.

Unit 5: Composite Materials

Level:	**3**
Unit type:	**Mandatory**
Assessment type:	**Internal**
Guided learning hours:	**60**

Unit introduction

A holistic understanding of composite materials is essential for technicians and those seeking employment in industries that utilise or have exposure to these materials. The aerospace, marine, automotive, construction, renewable energies and oil and gas industries exploit the use of composites in a number of forms. Composite materials are becoming more important in widespread engineering, and learners need to appreciate their principles and applications.

In this unit, you will explore the characteristics of the constituent parts of composite materials. You will examine the structural and mechanical properties of the fibres and matrices and how these properties improve when these are combined. You will investigate the applications of composites across a range of sectors and look at the end-of-product-life recyclability issues.

When working with composite materials, it is important to understand the fundamental basis of composite materials and how this affects the overall performance of the material. This unit will help to prepare you for a composite technician apprenticeship, as well as providing essential knowledge for design and manufacturing roles. In addition, this unit will help to prepare you for higher education and progression to other composite courses.

Learning outcomes

In this unit you will:

1 Examine the characteristics of fibres, reinforcements, core materials and sandwich panels

2 Examine the characteristics of matrices, including polymer (both thermoset and thermoplastic), metal and ceramic matrices and discuss how cure cycles affect the material properties

3 Examine the structural and mechanical properties of composite materials and how mechanical testing is used

4 Investigate the applications of composite materials across all sectors and discuss end-of-product-life issues (recyclability).

Content

What needs to be learned
Learning outcome 1: Examine the characteristics of fibres, reinforcements, core materials and sandwich panels
Characteristics of typical fibres used in fibre-reinforced plastic (FRP) composites • Types: glass, carbon, aramid, quartz, bio fibres, metallic, ceramic, thermoplastic, tissues, whiskers. • Properties, including tensile strength, compressive strength, specific modulus, impact resistance, environmental tolerance, fibre interface, electrical, cost. • How fibres are produced, including manufacturing techniques (pitch-based and polyacrylonitrile (PAN)-based for carbon), sizing, nomenclature for fibres (filament, tow, strand, yarn and roving) and the importance of the fibre interface. **Reinforcement styles** • Effects of crimping on fibres in a material. • Woven fabrics and the advantages and disadvantages of each: plain, twill, satin, basket, leno, hybrids. • Unidirectional, multiaxial, quadraxial, tapes, 3D stitching. • Random discontinuous mat (CSM). • Warp and weft, ±45°. • Preforms and braiding. • Laminate notation. **Core materials and sandwich panels** • Types of core materials (isotropic and anisotropic), to include honeycombs, foams, woods, and specialist cores (such as CoreMat). • Typical applications of various types of core materials. • Advantages and disadvantages of sandwich panels. • Why adhesives are essential in the use of sandwich panels.

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Learning outcome 2: Examine the characteristics of matrices, including polymer (both thermoset and thermoplastic), metal and ceramic matrices and discuss how cure cycles affect the material properties

Range of matrices and applications

- Advantages and disadvantages of polymer matrix composite (PMC), metal matrix composite (MMC) and ceramic matrix composite (CMC) and their applications.

Polymer matrix composites

- Thermoset range and their advantages and disadvantages and typical use, to include polyester, vinylester, epoxy, phenolic, bismaleimide, cyanate ester and emerging bio-resins.
- Thermoplastic range and their advantages and disadvantages and typical use, to include polyamide (PA6), polyetherimide (PEI), ultra-high molecule weight polyethylene (UHMWPE), polyether ether ketone (PEEK) and emerging bio-resins.

Curing of thermoset resins

- Difference between catalyst and hardener and how polymerisation occurs.
- Typical cure cycles of a range of thermoset resins and how variations in the temperature and pressures may affect material properties.
- Glass transition temperature (Tg) and post curing.

Learning outcome 3: Examine the structural and mechanical properties of composite materials and how mechanical testing is used

Structural properties

- Distinguish between the function of the fibre and the matrix to composite strength (fibre volume fraction) and why a broken or cut fibre will affect the strength of the laminate.
- The importance of balanced and symmetrical plies.
- Functions of the polymer matrix, to include supporting the material structure, transmitting forces between the fibres, protecting the fibres from handling and the environment, providing ductility and toughness.

Mechanical properties

- Desirable properties of composites – low density (lightweight), high stiffness, high tensile strength, low thermal expansion, high fatigue resistance, environmental tolerance.
- Limiting factors – maximum/minimum service temperature, UV degradation of aramid, impact tolerance of carbon.

Mechanical testing

- Destructive test procedures for characterising mechanical properties of a composite laminate.
- Demonstrate how fibre direction affects the mechanical strength of a layup (tensile tests on 0° fibres and on 90° fibres).

Learning outcome 4: Investigate the applications of composite materials across all sectors and discuss end-of-product-life issues (recyclability).

Applications of composites
• The benefits of composite materials over traditional materials in applications, to include the following sectors:
  ○ aerospace, e.g. wings and other high-performance structural components
  ○ marine, e.g. speedboat hulls, luxury yachts, jet skis
  ○ automotive, e.g. Formula 1®, mass production of body panels, suspension struts
  ○ construction, e.g. buildings, bridges, tanks, large art structures
  ○ renewables, e.g. wind energy, tidal energy, solar
  ○ oil and gas, e.g. pipework, pressure vessels, flooring.
Recyclability
• The complexities of recycling thermoset composites.
• Recycling methods currently available.
• Emerging recycling technology.
• End-of-life disposal issues for complex multi-material composite structures.

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Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Examine the characteristics of fibres, reinforcements, core materials and sandwich panels		
P1 Explain the characteristics and properties of at least two fibre types, outlining the importance of fibre arrangement.	M1 Compare the characteristics and properties of at least three fibre types, explaining the importance of fibre arrangement.	
P2 Numerically explain why sandwich panels can be stiffer than thin laminates.		
Learning outcome 2: Examine the characteristics of matrices, including polymer (both thermoset and thermoplastic), metal and ceramic matrices and discuss how cure cycles affect the material properties		
P3 Explain the characteristics of PMCs (thermoset and thermoplastic), MMCs and CMCs, including the advantages and disadvantages of each.	M2 Compare the characteristics of PMCs (thermoset and thermoplastic), MMCs and CMCs, including the advantages and disadvantages of each.	D1 Evaluate the characteristics of PMCs (thermoset and thermoplastic), MMCs and CMCs, including the advantages and disadvantages of each.
P4 Explain a thermoset cure cycle and its effect on the glass transition temperature (Tg) of the composite, including the use of post curing.		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 3: Examine the structural and mechanical properties of composite materials and how mechanical testing is used		
P5 Explain how the function of the fibre and matrix each contribute to the desired properties of the composite laminate.	M3 Compare how the function of the fibre and matrix contribute to the desired properties of the composite laminate and how the ply layup can affect properties.	D2 Evaluate how the function of the fibre and matrix contribute to the desired properties of the composite laminate and how these are mechanically tested.
Learning outcome 4: Investigate the applications of composite materials across all sectors and discuss end-of-product-life issues (recyclability)		
P6 Explain the use of composite materials across a range of sectors and why they have replaced traditional materials.	M4 Compare the use of composite materials across a range of sectors and explain why they have replaced traditional materials.	D3 Analyse the use of composite materials across a range of sectors and describe why they have replaced traditional materials.
P7 Explain the limitations of thermoset resins when it comes to recycling and discuss the options for end-of-life products.		

Further information for tutors and assessors

Resources

The special resources needed for this unit are:

- mechanical test equipment (such as a tensile test machine)
- a facility for manufacturing composite components.

Suggested reading

Chawla K – *Composite Materials: Science and Engineering (Materials Research and Engineering)* (Springer, 2013) ISBN 9780387743646

Gay D – *Composite Materials: Design and Applications*, 3rd edition (CRC Press, 2014) ISBN 9781466584877

Lin K – *Composite Materials: Materials, Manufacturing, Analysis, Design and Repair* (CreateSpace Independent Publishing Platform, 2015) ISBN 9781511585347

Websites	
www.compositesuk.co.uk/composite-materials	Simple definitions of composites.
www.gurit.com/-/media/Gurit/Datasheets/guide-to-composites.ashx	A comprehensive guide to composites and structures.

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Examine the characteristics of fibres, reinforcements, core materials and sandwich panels	Characteristics of fibres, reinforcements, core materials and sandwich panels	A report covering the characteristics of fibres, reinforcements and core materials with a numerical description of the stiffness of sandwich panels.
2 Examine the characteristics of matrices, including polymer (both thermoset and thermoplastic), metal and ceramic matrices and discuss how cure cycles affect the material properties	Characteristics of PMCs, MMCs and CMCs	A report covering the characteristics of matrices, including polymer (both thermoset and thermoplastic), metal and ceramic matrices and a discussion of how cure cycles affect the material properties.
3 Examine the structural and mechanical properties of composite materials and how mechanical testing is used	Structural and mechanical properties of composite materials	A report covering the structural and mechanical properties of composite materials. This could be a theoretical or a test report discussing and analysing the data from a practical tensile test carried out on UD composite coupons.
4 Investigate the applications of composite materials across all sectors and discuss end-of-product-life issues (recyclability)	Applications of composite materials	A report covering the application of composite materials across a variety of sectors, with a discussion of end-of-product-life disposal.

Assessment guidance

Learning outcome 1 – Characteristics of fibres, reinforcements, core materials and sandwich panels

For Merit standard, learners will compare the characteristics in their evidence of at least three fibres types and how they are manufactured. When explaining the production method of the fibres, they will include the relative nomenclature of fibres and state how these fibres are prepared for use in composites by the sizing treatment and why this is important. When comparing the characteristics of the fibre types, learners will clearly compare the relative strength, density, toughness, cost and environmental impact of the three materials. Learners will then link the fibre characteristics to the fibre arrangements and show how the reinforcement styles affect the fibre properties, such as material crimping and drapeability.

Overall, the evidence will be logically structured, technically accurate, methodical and easy to understand.

For Pass standard, learners will give in their evidence a clear and qualitative explanation of the characteristics of two fibre types and their manufacturing methods. When comparing the characteristics of the fibre types, learners will compare some of the mechanical properties and will discuss reinforcement styles. For P2, learners will discuss the difference between the variety of core materials and list common applications. They will numerically demonstrate the effect of the thickness of a core material on the stiffness of a sandwich panel.

Overall, the explanations will be structured logically although basic in parts and they may contain minor technical or diagrammatic errors.

Learning outcome 2 – Characteristics of PMCs, MMCs and CMCs

For Distinction standard, learners will clearly show their comprehension of the differences between thermoset, thermoplastic, metal and ceramic matrices and will discuss the advantages and disadvantages of each matrix system (PMC, MMC, CMC), while demonstrating why the materials are used in specific applications. They will discuss in depth the merits of the various types of thermoset and thermoplastic resins and will describe typical applications and sectors for each.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For Merit standard, learners will provide detailed information on the characteristics of each of the matrix systems (PMC, MMC, CMC) and describe the advantages and disadvantages of each. They will be able to compare the differences within a selection of thermoset resins and within a selection of thermoplastic resins and explain their typical applications. They will compare the characteristics of the matrices and present this in a way that is easy to understand, such as a table.

Overall, the evidence should be logically structured, technically accurate and easy to understand.

For Pass standard, learners will acknowledge the differences between the resin systems and will provide an advantage and disadvantage of each matrix system (PMC, MMC, CMC). They will compare some resin systems within the thermoset family and within the thermoplastic family and be able to list a typical application for each.

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For P4, learners will be able to describe how polymerisation occurs both at room temperature and at elevated heat, acknowledging the difference between a catalyst and a hardener. Learners will provide an example of a typical cure cycle and how this will affect the glass transition (Tg) of the material. They will explain how a post-cure of thermoset materials will elevate the Tg of the material.

Overall, the evidence will be structured logically. The evidence may be basic in parts, for example making general statements about each resin system, and may contain technical inaccuracies such as the application of some matrices.

Learning outcome 3 – Structural and mechanical properties of composite materials

For Distinction standard, learners will show how the fibre gives strength to a composite component and will discuss the effects of cut or broken fibres.
A theoretical discussion or mechanical testing of tensile coupons when fibres are laid at 0°, 90°, and ±45° can be used to show how the fibre and matrix contribute to composite strength. Learners will acknowledge the importance of balanced and symmetrical plies and the consequences of unbalanced layups. They will summarise by showing how the fibre and matrix achieve the desirable properties of the composite material, and how these properties are tested.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For Merit standard, learners will clearly show how the fibre volume fraction contributes to the properties of a composite, and they will explain the mechanical properties that both the fibre and the matrix provide the composite. A theoretical discussion or mechanical testing can be used to demonstrate how the ply layup of the component can affect mechanical properties, including the effects of unbalanced and unsymmetrical plies.

Overall, the evidence should be logically structured, technically accurate and easy to understand.

For Pass standard, learners will discuss what the desired properties of a composite material are and how the resin and the fibre both contribute to these mechanical properties. They will acknowledge the importance that fibre volume fraction plays in composite strength.

Overall, the explanations will be logically structured, although basic in parts.

Learning outcome 4 – Applications of composite materials

For Distinction standard, learners will provide a comprehensive analysis on the use of composite materials across the range of at least five sectors. They will use examples to discuss the traditional materials previously used and how these have been superseded by composites, and the advancements that have been possible due to the use of composites.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For Merit standard, learners will compare the use of composite materials across the range of at least five sectors. They will use examples to discuss the traditional materials previously used and how these have been superseded by composites, and the advancements that have been possible due to the use of composites.

Overall, the evidence should be logically structured, technically accurate and easy to understand.

For Pass standard, learners will explain the use of composite materials across the range of at least four sectors. They will use examples to discuss the traditional materials previously used and how these have been superseded by composites, and the advancements that have been possible due to the use of composites.

For P6, learners will discuss the difficulties with recycling thermoset composites and look at the current methods for recycling and highlight any emerging processes.

Overall, the explanations will be structured logically, although basic in parts.

Unit 6: Composites Manufacturing Processes

Level: 3

Unit type: Mandatory

Assessment type: Internal

Guided learning hours: 60

Unit introduction

Advanced composites are produced in a variety of different ways using different materials and manufacturing processes. It is imperative to understand which process will provide the most cost-effective and reliable method of production for a component. The methods used for the bonding, fastening and assembly of the components are just as critical for the overall performance of the composite component.

In this unit, you will gain an understanding of the range of manufacturing processes available and how these influence product design. It details how components are trimmed and assembled to produce the final product and will give you the practical experience of manufacturing, bonding and assembling their own component.

Working as a composite technician, it is important to understand the fundamental basis of composite manufacturing processes and how this affects the overall performance of the material. This unit will help to prepare you for a composite technician apprenticeship, as well as providing essential knowledge for design and manufacturing roles. In addition, the unit will help to prepare you for higher education and progression to other composite courses.

Learning outcomes

In this unit you will:

1 Examine the differences, advantages and disadvantages of key manufacturing processes

2 Investigate how composite component design decisions affect component manufacturability

3 Examine bonding techniques, trimming and finishing methods and assembly techniques

4 Carry out a process to manufacture a three-part composite component that includes bonding, fasteners and assembly techniques.

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Content

What needs to be learned
Learning outcome 1: Examine the differences, advantages and disadvantages of key manufacturing processes
Processes used in the manufacture of thermoset composite materials • Wet lay. • Prepreg. • Resin transfer: infusion (RI), film (RFI), moulding (RTM), vacuum-assisted (VARTM). • Filament winding. • Automated tape and fibre placement (ATL and AFP). • Hot press. **Processes used in the manufacture of thermoplastic composite materials** • Hot press. • Extrusion. • Pultrusion. • Compression moulding. • Injection moulding. • Bulk and sheet moulding. • Rotational moulding. • Blow moulding. **Processes used in the manufacture of ceramic matrix composites (CMC) and metal matrix composites (MMC)** • CMC – prepreg form, porous preform infiltration techniques. • MMC – liquid-phase processes, solid-liquid process, deposition techniques.

Learning outcome 2: Investigate how composite component design decisions affect component manufacturability

Tooling design

- Process of producing a tool from a CAD drawing to manufacturing the finished tool.
- Draft angles for demoulding.

Tooling materials

- Use of different materials in tooling design and selection criteria:
  - coefficient of thermal expansion (CTE)
  - tolerances
  - process curing parameters (temperature and pressure)
  - geometrical shape of design
  - number of components.

Manufacture of tooling

- Machining of metallics, composite (patterns, plugs and moulds), tooling block, 3D printing (additive layer manufacturing (ALM), foam, MDF, etc.).
- Tooling types: male, female, multi-part, closed, open, mandrels, matched.

Learning outcome 3: Examine bonding techniques, trimming and finishing methods and assembly techniques

Adhesives and bonding techniques

- Types of adhesives:
  - film, paste, liquid, shim
  - epoxy, acrylic, polyurethanes, silicones.
- Surface preparation: mechanical, chemical, solvent.
- Curing: heat, ultraviolet light, moisture, anaerobic reaction and anionic (cyanoacrylates), bonding jigs.
- Bonded joint designs.
- Co-curing, co-bonding and secondary bonding.
- Failure modes in bonds: adhesive, cohesive, substrate.
- Importance of adhesives with core materials.
- Bonding of metallic and composite components, including issues of galvanic corrosion with carbon.

Trimming and finishing methods

- Consider different materials when examining methods for:
  - marking out PMC mouldings: height gauges, scribes, moulded scribe lines, trimming templates
  - cutting and trimming PMC mouldings: cutting wheels and discs, saws (reciprocating, band saw), routers, trim jigs
  - drilling mouldings: drill jigs, hole saws, countersinks
  - sanding and polishing PMC mouldings.

Assembly techniques
• Mechanical fastening techniques for PMCs, including:
  ○ thread inserts
  ○ quick-release fasteners
  ○ anchor nuts
  ○ rivets
  ○ thermo welding (thermoplastics).

Learning outcome 4: Carry out a process to manufacture a three-part composite component that includes bonding, fasteners and assembly techniques
Applying manufacturing processes • Selection of a suitable manufacturing process for the components. • Production of the three components. **Trimming and finishing techniques** • Preparing and marking out of components. • Selection of trimming and finishing techniques and equipment. • Trimming and sanding of components. • Final geometry check against the requirements. **Assembly of components** • Bond two or more of the components using a suitable adhesive. • Mechanically join two or more of the components using an appropriate fastener. • Final geometry check, inspection and testing, e.g. visual check, tap test, ultrasound.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Examine the differences, advantages and disadvantages of key manufacturing processes		
P1 Explain the characteristics of composite manufacturing processes for thermoset and thermoplastics.	M1 Compare the characteristics of thermoset, thermoplastic, ceramic matrix and metal matrix composite manufacturing processes.	D1 Analyse the use of thermoset, thermoplastic, ceramic matrix and metal matrix composite manufacturing processes in different sectors.
Learning outcome 2: Investigate how composite component design decisions affect component manufacturability		
P2 Outline how a local composite company manufactures a tool from CAD drawings, stating the key costs within the process.	M2 Investigate how a local composite company manufactures a tool from CAD drawings, explaining the key costs within the process.	D2 Evaluate why certain features exist on the tool.

Learning outcome 3: Examine bonding techniques, trimming and finishing methods and assembly techniques		
P3 Describe a typical process for adhesive bonding and explain why surface preparation is important and the failure modes that can occur in bonds.	M3 Compare surface preparations for metallic and composite adhesive bonding and explain the issues of bonding metals to carbon.	
P4 Describe a typical process for marking out and trimming a composite component and explain the techniques used for drilling carbon fibre laminates.		
P5 Describe a typical process for joining composites with mechanical fasteners and explain the differences between joining thermoset and thermoplastic composites.		
Learning outcome 4: Carry out a process to manufacture a three-part composite component that includes bonding, fasteners and assembly techniques		
P6 Explain the processes used to manufacture, trim and assemble the composite component.	M4 Analyse what processes were effective for the manufacture, trim and assembly of the composite component.	D3 Justify the processes chosen to manufacture, trim and assemble the composite component.

Further information for tutors and assessors

Resources

The special resources needed for this unit are facilities or access to facilities that manufacture composite components.

Suggested reading

Textbooks

Campbell F C – *Manufacturing Processes for Advanced Composites* (Elsevier Science, 2003) ISBN 9781856174152

Dorworth L C, Gardiner G L and Mellema G M – *Essentials of Advanced Composite Fabrication & Repair* (Aviation Supplies and Academics, Inc., 2009) ISBN 9781560277521

Strong B – *Fundamentals of Composites Manufacturing: Materials, Methods, and Applications* (Society Manufacturing Engineers, 2007) ISBN 9780872638549

Websites

www.gurit.com/-/media/Gurit/Datasheets/guide-to-composites.ashx	A comprehensive guide to composites and structures.
www.ijrmet.com/vol4issue2/spl2/4-Bhaskar-Chandra-Kandpal.pdf	Production technologies for metal matrix composites.

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Examine the differences, advantages and disadvantages of key manufacturing processes	Manufacturing processes for PMC, MMC and CMC	A written report in tabular format that covers the key manufacturing processes with advantages, disadvantages, sectors and common products.
2 Investigate how composite component design decisions affect component manufacturability	Investigate tooling for composite manufacture in a local company	A written report based on a company visit to explore how a CAD drawing is used to produce tooling. Learners should have the opportunity to ask questions about key costs and tool features.
3 Examine bonding techniques, trimming and finishing methods and assembly techniques	Bonding, trimming and assembly techniques	A written report that describes bonding techniques, trimming and finishing methods and assembly techniques.
4 Carry out a process to manufacture a three-part composite component that includes bonding, fasteners and assembly techniques	Manufacture of a three-part composite component	A written report, including annotated sketches and photographs, showing learners manufacturing, trimming and assembling a three-part composite component. Learners' evidence should be supported with observation records.

Assessment guidance

Learning outcome 1 – Manufacturing processes for PMC, MMC and CMC

For Distinction standard, learners will give a detailed analysis of the the use of the different manufacturing methods listed in the assessment criterion, stating the advantages and disadvantages of each. They will identify the typical sectors that use these manufacturing methods and common products produced using these methods. For clarity, the information can be presented in a table.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will show the characteristics of some of the manufacturing methods listed within the learning outcome, stating the advantages and disadvantages of each. They will identify the typical sectors that use these manufacturing methods and common products that are produced using these methods. For clarity, the information can be presented in a table.

Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will explain the characteristics of some of the manufacturing methods listed within the learning outcome, stating the advantages and disadvantages of each. Learners will identify the typical sectors that use these manufacturing methods and common products that are produced using these methods. For clarity, the information can be presented in a table.

Overall, the explanations will be structured logically, although basic in parts, and they may contain minor technical errors.

Learning outcome 2 – Investigate tooling for composite manufacture in a local company

For Distinction standard, learners will detail why certain features exist on a tool, such as closing lugs, draft angles, resin drains, witness lines. They will explain how the features help the manufacturing process and the implications if the feature did not exist. They will discuss the cost of the features and compare this to the potential cost implications if the feature did not exist.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will independently investigate the process of producing a tool from a CAD drawing in a local company. They will explain the costs associated with each stage, such as the software, machining or tooling production costs, tooling material selection for the process, production costs, prototyping, number of tools required etc.

Overall, the evidence will be logically structured, technically accurate, methodical and easy to understand.

For Pass standard, learners will outline the process of producing a tool from a CAD drawing in a local company. They will explain some of the costs associated with each stage, such as the software, machining or tooling production costs, tooling material selection for the process, production costs, prototyping, number of tools required etc.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor errors.

Learning outcome 3 – Bonding, trimming and assembly techniques

For Merit standard, learners will compare the methods and techniques used in surface preparation for both composite and metallic substrates. They will describe how and why they differ and discuss the implications of bonding metallic and carbon substrates.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the methods and techniques for surface preparation for adhesive bonding. They will then describe a typical process for adhesive bonding and explain the common failure modes of bonded joints. For P4, they will describe some of the equipment that can be used for marking out components and the tools that are used for trimming. Learners should talk about drill speed and drill bit types when explaining how to drill carbon fibre laminates. For P5, learners will describe how composite components can be joined with mechanical fasteners and detail a typical process. Learners will recognise the differences in joining thermoset and thermoplastic composites, such as the risks of defects that can occur in thermosets and the use of thermo welding in thermoplastics.

Overall, the explanations will be logically structured, although basic in parts and they may contain minor errors.

Learning outcome 4 – Manufacture of a three-part composite component

For Distinction standard, learners will show in their evidence that they have worked safely, accurately and effectively to manufacture, trim and assemble a composite component. An assessment of effectiveness might include whether learners worked methodically, skilfully and confidently during the practical phase of the assessment to ensure that the processes were carried out using best practice techniques to produce a good-quality, reliable result, free of flaws. Learners will surface prepare the composite prior to bonding and may countersink mechanical fastenings where appropriate. Learners' evidence will also show that they were able to justify their choice of techniques to produce, trim and assemble the composite component. For example, they may have decided to use mechanical fasteners in one area instead of adhesive due to the surface finish of their component.

Overall, the evidence will be easy to read and understand by a third party who may or may not be an engineer. It will be structured logically and will use correct engineering terms.

For Merit standard, learners will show in their evidence that they have worked safely and accurately to manufacture, trim and assemble a composite component. An assessment of effectiveness may be made by measuring critical component dimensions once the component is trimmed and finished, examining the overall quality of the assembly and summarising how the processes could have been improved.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will show in their evidence how they carried out the safe manufacture, trim and assembly of a component. They will provide a detailed explanation of how the preparation and manufacturing processes were carried out and provide evidence of the safety precautions taken.

Overall, the evidence will be structured logically. The evidence may be basic in parts, for example not recording all of the steps of the processes being carried out, and may contain technical inaccuracies or omissions, such as the occasional use of non-technical language.

Unit 7: Composites Engineering Product Design and Manufacture

Level: 3

Unit type: Mandatory

Assessment type: Internal

Guided learning hours: 60

Unit introduction

Composites engineering products are part of our daily lives, from aircraft to sports equipment. Composites engineering products are designed as a result of the identification of a need or opportunity, and composites engineers will use creative skills and technical knowledge to devise and deliver a new design or improvements to an existing design. For example, advances in the development of aircraft led to the Boeing Dreamliner and Airbus A350, both of which have more than 50 per cent of their parts designed and made using composite materials.

In this unit, you will examine what triggers changes in product design and the use of composites engineering products and the typical challenges that composites engineers face, such as designing out safety risks. You will learn how material properties and manufacturing processes have an impact on the design of a composites engineering product. Finally, you will use an iterative process to develop a design for a composites engineering product by interpreting a brief, producing initial ideas and then communicating and justifying your suggested solution. You will draw on and apply knowledge and understanding from other units, for example by justifying the chosen materials and an appropriate composites engineering process, taking into account how its use reduces the carbon footprint of a product and the cost/benefit of the material and process chosen.

Learning outcomes

In this unit you will:

1 Demonstrate an understanding of design criteria and constraints

2 Demonstrate knowledge and understanding of composites engineering methodologies, processes, features and procedures to an iterative design

3 Source information, analyse data and make connections between composites engineering concepts

4 Develop and communicate reasoned design solutions with appropriate justification.

Content

What needs to be learned
Learning outcome 1: Demonstrate an understanding of design criteria and constraints
Design triggers The triggers that stimulate composites engineering design activity, including: • market pull/technology push (product and process) • demand profitability • innovation market research (product/process) • performance issues • sustainability (carbon footprint) • designing out risk • competition. **Design challenges** Commercial-, regulatory- or public policy-based trends that challenge current technology or design, including: • reduction of energy wasted during design of a composites engineered product • reduction of energy wasted during operation of a composites engineered product • reduction of physical dimensions • reduction of product mass • increase in component efficiency • energy recovery features • reduced product life cycle costs • reduced use of resources in high-value manufacturing • sustainability issues throughout the product life cycle (raw materials, manufacture, packaging and distribution, use and reuse, end of life) • designing out risk (for individual employees and customers). **Equipment level and system level constraints and opportunities** Factors that place limitations and offer opportunities at equipment level on the design of composites engineering products, including: • reasons for selecting different solutions for equipment interfaces (mechanical, electrical, hydraulic, software) • systems integration compromises (cooling, location for optimum equipment performance, bonding, centre of gravity, electrical and electronic compatibility) • equipment product design specification (PDS) (shortcomings absorbed at system level, electromagnetic compatibility (EMC), mass, cooling) • cost-effective manufacture (capital outlay, use of tooling, set-up cost).

Material properties Properties, modes of failure and protection of composites engineering materials and components that impact on their selection when designing a composites engineering product, including: • mechanical properties • physical properties • thermal properties • electrical and magnetic properties • modes of failure • surface treatments and coating. **Manufacturing processes** *Characteristics and effects of manufacturing processes* that impact on the selection of composites engineering materials and components when designing a composite engineering product, including: • processes for composites (layup, additive, moulding, machining, forming, pressing, powder, bonding, joining, assembly) • processes for polymers (additive, casting, moulding, extrusion, thermoforming) • processes for ceramics (additive, casting, forming) • processes for automation (automated layup, tow placement) • scales of manufacture (one-off, small batch, large batch, mass, continuous).
Learning outcome 2: Demonstrate knowledge and understanding of composites engineering methodologies, processes, features and procedures to an iterative design
Design for a customer Meeting customer needs during composites engineering design activity, including: • types of customer (internal, external) • product and service requirements (performance specifications, compliance to operating standards, manufacturing quantities, reliability/product support, product life cycle, usability, anthropometrics) • product design specification/criteria (cost, quantity, maintenance, finish, materials, weight, aesthetics, product life cycle, sustainability, carbon footprint, reliability, safety, testing, ergonomics, usability, competition, market, manufacturing facility, manufacturing constraints, manufacturing processes) • commercial protection (patents, registration, copyright, trademarks).

Regulatory constraints and opportunities

Regulatory factors that place limitations and opportunities on the design of composites engineering products, including:

- legislation
- standards
- codes of practice
- national and international certification requirements
- environmental constraints (sustainability, carbon footprint, product life cycle)
- health and safety
- security (product and process).

Market analysis

Composites engineering goals in terms of marketing when designing a composites engineering product, including:

- unique selling point (USP)
- benefits of the design
- obsolescence.

Performance analysis

Composites engineering goals in terms of performance when designing a composites engineering product, including:

- product form
- product functionality
- technical considerations
- choice of materials and process
- environmental sustainability (impact, carbon footprint)
- interactions with other components (including metal)
- likelihood of failure or wear.

Manufacturing analysis

Composites engineering goals in terms of manufacturing when designing a composites engineering product, including:

- processes for manufacturing/assembly
- manufacturing requirements
- quality indicators
- environmental sustainability (impact, carbon footprint)
- design for manufacture.

Learning outcome 3: Source information, analyse data and make connections between composites engineering concepts

Design proposals

Initial and developed propositions to improve a composites engineering product, including:

- technical design criteria idea generation (context, creativity, range)
- initial design ideas (fitness for purpose, refinements, recognition of constraints)
- developed design idea (aesthetics, ergonomics, sizes, mechanical principles, material requirements, manufacturing processes, assembly arrangements, cost estimations, factor of safety, selection procedures for bought out components)
- use of information sources (data books, standards, material data sheets).

Communication designs

Communication of an initial and a developed proposition to improve a composites engineering product, including:

- freehand sketching and diagrams (2D and 3D, illustrations, technical)
- graphical techniques (charts, keys, shading, animation, symbols, conventions)
- written skills (annotation, technical language, interpreting results)
- documentation (detail and assembly orthographic projections, specifications, parts list, materials list, production plan, ply layup list, assembly diagrams, flowchart, design log).

Iterative development process

Using an iterative process to improve a composites engineering product, including:

- refining a task or process (analysing, adapting, enhancing)
- cyclic process (logical non-linear approach, focus on product design specification/criteria).

Learning outcome 4: Develop and communicate reasoned design solutions with appropriate justification

Statistical methods
• Statistical techniques as applied to composites engineering problems, including:
  ○ statistical measurement (discrete/continuous, mean, median, mode, variance)
  ○ data handling:
    – graphical representation (bar chart, pie chart, frequency table, histogram, cumulative frequency diagram or graph)
    – frequency distributions (normal, skewed, standard deviation).
Validating designs
Rationalise choices made when generating a developed proposition to improve a composites engineering product, including:
• objective referencing against product design specification/criteria
• objective referencing against weighted matrix
• indirect benefits and opportunities
• balancing benefits and opportunities with constraints (cost-benefit analysis, environmental benefits, health and safety risks, product life cycle considerations)
• design for manufacturing
• further modifications (technology-led adaptations).

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Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Demonstrate an understanding of design criteria and constraints		
P1 Describe the design criteria and design constraints that need to be considered when designing composite components/structures.	M1 Analyse the design criteria and design constraints that apply to a given composites engineering manufacturer.	D1 Compare the design constraints that apply to composites manufacturers that produce structures for different industrial sectors.
Learning outcome 2: Demonstrate knowledge and understanding of composites engineering methodologies, processes, features and procedures to an iterative design		
P2 Describe the different processes and materials that can be utilised to optimise composite structures.	M2 Explain the relationship between the design options employed and the manufacturing process used to produce a composite structure.	D2 Make recommendations that optimise a design solution and justify the rational for the changes.
P3 Produce a design of a composite structure from a design brief.	M3 Evaluate the design solution produced from a design brief.	

Learning outcome 3: Source information, analyse data and make connections between composites engineering concepts		
P4 Describe the different sources of information available to the composites designer.	M4 Evaluate the usefulness of different sources of data.	D3 Make fully justified recommendations to ensure that optimal material properties will be realised by a composite structure.
Learning outcome 4: Develop and communicate reasoned design solutions with appropriate justification		
P5 Describe the role statistical analysis has in the prediction of the performance and strength of a composite structure.	M5 Produce an evaluation matrix for a range of design solutions relating to a design brief.	D4 Analyse the use of an evaluation matrix and suggest how the process can be modified to produce intended outcomes.
P6 Describe the processes adopted to ensure designs meet the design specification.		

Further information for tutors and assessors

Resources

The special resources needed for this unit are:

- case studies of composites engineering companies
- access to CAD software typically used in composites engineering companies
- access to engineering data books, and relevant national and international standards.

Suggested reading

Textbooks

SAE International – *Composite Materials Handbook (CHM-17) Volume 1: Polymer Matrix Composites* (SAE International, 2013) ISBN 9780768078114

SAE International – *Composite Materials Handbook (CHM-17) Volume 2: Polymer Matrix Composites* (SAE International, 2012) ISBN 9780768078121

SAE International – *Composite Materials Handbook (CHM-17) Volume 3: Polymer Matrix Composites* (SAE International, 2013) ISBN 9780768078138

Websites

www.900gpa.com	Comprehensive database of composite engineering materials
www.matweb.com	Fully searchable material properties database

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Demonstrate an understanding of design criteria and constraints	Design and constraints	A written report based on case studies of composite manufacturing companies. Ideally, learners will use their own employer as their case study. Industrial visits to composites manufacturers that supply different sectors will give learners a broad view of the topic. For example, learners will visit an aerospace composites manufacturer and a marine composites manufacturer.
2 Demonstrate knowledge and understanding of composites engineering methodologies, processes, features and procedures to an iterative design	The relationships between design and manufacturing processes	Learners will design a composite structure that meets the requirements of a given design brief. All learners must have the same design brief. A written report that details the materials and manufacturing processes that could be employed to manufacture the structure they have designed.
3 Source information, analyse data and make connections between composites engineering concepts	The use of data and information during design and manufacturing	A written report detailing the different sources of data available during the manufacture of composites structures or components. Learners will then use sources of data to optimise at least two mechanical properties of the design solution from assignment 2.
4 Develop and communicate reasoned design solutions with appropriate justification	Creating design solutions that meet the design brief	A written report detailing the use of statistical analysis to influence design decisions and how design solutions are validated. Learners will pool their design solutions from assignment 2 and will individually produce an evaluation matrix to identify the best solution.

Learning outcome 1 – Design and constraints

For Distinction standard, learners will make comparisons between the design constraints imposed on composites manufacturing companies that produce structures and/or components for different industrial sectors. For example, learners will compare the structural requirements of components produced for the aerospace sector and the rail industry. Examples of the requirements from each sector will be included to illustrate the arguments put forward. Overall, the work will be technically accurate and will be written using language appropriate for the intended audience.

For Merit standard, learners will identify and explain the design criteria and constraints that are imposed on a given manufacturer. Ideally, this will be their employer. Learners will give sound reasons for the use of the design criteria and the constraints that are imposed, and will offer suggestions on how the company can overcome the constraints.

For Pass standard, learners will identify and describe the design constraints and criteria for a given composites engineering manufacturer. Overall, the language used will be appropriate for the intended audience and will use technical vocabulary, and minor inaccuracies are acceptable.

Learning outcome 2 – The relationships between design and manufacturing processes

For Distinction standard, learners will make recommendations that could be incorporated into a design solution that optimise the manufacturing procedures. For example, the inclusion of location dowels into a two-part mould that aid the correct alignment of the mould sections, or how the design solution could be altered to allow batch production instead of one-off production. Overall, the work will be technically accurate and will be written using language appropriate for the intended audience.

For Merit standard, learners will identify and explain the manufacturing processes that will be utilised to produce a structure or component from their design solution. Learners will conduct an evaluation of the design solution to ensure it complies with the design brief and that its manufacture is viable, using the manufacturing processes selected. They will give sound reasons for the use of the manufacturing processes selected.

For Pass standard, learners will produce a viable design solution from a given design brief and will describe the manufacturing processes that could be used in order to produce the structure or component. Overall, the language used will be appropriate for the intended audience and will use technical vocabulary, however, minor inaccuracies are acceptable.

Learning outcome 3 – The use of data and information during design and manufacturing

For Distinction standard, learners will use a range of data sources to research and specify alternative materials that will optimise at least two mechanical properties of the design solution from assignment 2. For example, changing the material specification of the fibre material would enable a weight reduction in the composite structure or component while maintaining overall rigidity. Learners will give full justification for their material choices, giving practical examples where appropriate. Overall, the work will be technically accurate and will be written using language appropriate for the intended audience. All sources of information will be referenced accurately.

For Merit standard, learners will compare and contrast at least six of the different sources of information available during the design and manufacture processes. They will detail what information each source contains and the advantages/limitations of using these information sources during design and manufacture.

For Pass standard, learners will accurately describe the information contained in at least six different sources of information that are available to a composites designer.

Learning outcome 4 – Creating design solutions that meet the design brief

For Distinction standard, learners will analyse the use of the evaluation matrix and give justified recommendations as to how the process could be improved further. For example, they could suggest the completion of the evaluation matrix is carried out in a small team of people rather than by an individual, therefore avoiding personalisation.

For Merit standard, learners will produce an evaluation matrix for each design solution in the class group from assignment 2. They will identify the overall best solution of those presented and will give sound reasons why the chosen solution is the best.

For Pass standard, learners will clearly describe the different statistical methods that can be used during the design and manufacturing processes, and how design solutions are validated against the initial design brief.

Unit 8: Defects, Detection and Repair Processes in Composites Mouldings

Level: 3

Unit type: Mandatory

Assessment type: Internal

Guided learning hours: 60

Unit introduction

Damage to composite components is complex and can cause catastrophic failure if not detected. An understanding of the defects that can occur, the inspection techniques available and the repair processes that can be used on composites is essential for technicians and those seeking employment in industries that use composite components.

In this unit, you will investigate the range of available inspection techniques to identify both manufacturing and in-service defects in composite components. There will be the opportunity to use established repair methods to repair a composite component and to check the integrity of the repair using non-destructive testing (NDT).

Working as a composite technician, it is important to understand the fundamental basics of composite defects and repairs and how this affects the overall performance of the composite component. This unit will help to prepare you for a composite technician apprenticeship, as well as providing essential knowledge for design and manufacturing roles. In addition, the unit will help to prepare you for higher education and progression to other composite courses.

Learning outcomes

In this unit you will:

1. Investigate in-service and manufacturing defects that can occur in a composite component
2. Examine defect inspection methodologies (inspection, evaluation and test) and processes for composites
3. Investigate the range of repair procedures, their characteristics and applications
4. Carry out processes to inspect and safely repair a polymer composite component, including post-repair inspection.

Content

What needs to be learned
Learning outcome 1: Investigate in-service and manufacturing defects that can occur in a composite component
In-service defects and how they occur, including: • impact damage, delamination, disbond, water ingress (and osmosis), overload (mechanical and thermal), core crush, lightning strike, dents and dings, penetration, blisters, surface cracks, abrasion/erosion, fatigue, ductile and brittle fracture, creep • typical in-service defects in composites found across the sectors of aerospace, marine, automotive, renewables, construction and oil and gas. **Manufacturing defects and how they occur, including:** • inclusions, delamination, surface finish, incorrect material, bridging, broken fibres, ply orientation, incorrect joint type (overlap, gaps), wrinkles, voids, resin-rich areas, porosity, incomplete curing, shrinkage, dimensional tolerances • the implications of these defects across the sectors of aerospace, marine, automotive, renewables, construction and oil and gas.
Learning outcome 2: Examine defect inspection methodologies (inspection, evaluation and test) and processes for composites
Non-destructive inspection techniques • Methods for identifying defects, including measuring equipment for dimensional checks (co-ordinate measuring machines), touch, acoustic emission (including tap test), thermography (active and passive), ultrasonic, radiography, shearography. • Key costs and skill levels associated with the test methods. • Typical inspection techniques and the frequency of checks used across the sectors of aerospace, marine, automotive, renewables, construction, and oil and gas. **Defining allowable defects** • Destructive mechanical tests that are used to define the allowable defects in service, including tensile, compression, three-point bend, fatigue, environmental (such as hot/wet testing), impact testing. **Recording, reporting and standards** • Adherence to requirements such as customer requirements, company standards and quality assurance documentation across the sectors. • Standards for test methods such as British Standards (BS EN 13477:2010, BS EN 1308:2016), ISO (ISO 14692) and ASTM (ASTM E2533 – 17).

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Learning outcome 3: Investigate the range of repair procedures, their characteristics and applications
Understand the different repair procedures available • Patch repairs, including: ○ resin injection (potting or filling), delamination injection, bonded scarf, bonded flush, repair curing using a heat source, doubler, tapered plug repair, wet lay patching, prepreg patching, core repair (patching and potting). • Bolted repairs, including the use of sealants. **Typical repairs for structures and applications** • Laminate, partial thickness laminate, sandwich panel, single-sided access, double-sided access, temporary, cosmetic, structural, non-structural. **Structural repair manuals (SRMs) and documentation** • Familiarisation with SRM documentation for a range of sectors.
Learning outcome 4: Carry out processes to inspect and safely repair a polymer composite component, including post-repair inspection
Damage assessment • Preliminary survey of damage to determine size/depth of area needing repair. • Classification of damaged component using NDT. • Selection of repair style using approved documentation for the sector. **Repair** • Removal of damaged materials. • Cleaning, degreasing and drying the composite material in the area to be repaired. • Prepare repair to appropriate size. • Application of repair. **Final inspection and reporting** • Quality control inspection checks, including visual, and physical non-destructive techniques (such as tap test), geometrical and dimensional checks. • Reporting of repair, including health and safety procedures followed.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Investigate in-service and manufacturing defects that can occur in a composite component		
P1 Outline manufacturing and in-service defects and how they typically occur.	M1 Compare manufacturing and in-service defects and how they typically occur.	D1 Discuss the implications of manufacturing and in-service defects across a range of sectors.
Learning outcome 2: Examine defect inspection methodologies (inspection, evaluation and test) and processes for composites		
P2 Describe methods of composite inspection.	M2 Compare methods of composite inspection and state how these are carried out to requirements.	D2 Investigate the range of test and quality standards used for defect inspection across a range of sectors.
P3 Describe mechanical destructive tests and how they define allowable defects.		

Learning outcome 3: Investigate the range of repair procedures, their characteristics and applications		
P4 Explain what inspection and repair methods would be effective for the detection and repair of damage to a given composite component.	M3 Analyse what inspection and repair methods would be effective for the detection and repair of damage to a given composite component, including final inspection methods.	
P5 Explain the procedures and related safety precautions for patch and non-patch repairs to composite components.		
Learning outcome 4: Carry out processes to inspect and safely repair a polymer composite component, including post-repair inspection		
P6 Inspect and repair a composite component safely, including appropriate checks and tests.	M4 Complete the repair of a damaged composite component safely and accurately, including appropriate inspections, checks and tests.	D3 Refine, during the process, the repair to a damaged composite component safely to ensure component integrity, including appropriate inspections, checks and tests.

Further information for tutors and assessors

Resources

The special resources needed for this unit are facilities or access to facilities to carry out composite repairs.

Suggested reading

Textbooks

Dorworth L C, Gardiner G L and Mellema G M – *Essentials of Advanced Composite Fabrication & Repair* (Aviation Supplies and Academics, Inc., 2009) ISBN 9781560277521

Jefferson A J and Arumugam V – *Repair of Polymer Composites: Methodology, Techniques and Challenges* (Woodhead Publishing, 2018) ISBN 9780081022634

Kim Y J (editor) – *Advanced Composites in Bridge Construction and Repair* (Woodhead Publishing, 2018) ISBN 9780081013724

Websites

www.compositesuk.co.uk/system/files/documents/repairoffrpstructures.pdf	Best practice guide – repair of FRP structures
www.compositesuk.co.uk/system/files/documents/review_of_composites_standardisation_activities.pdf	Review of composite NDT standards
www.gurit.com/-/media/Gurit/Datasheets/guide-to-composites.ashx	A comprehensive guide to composites and structures
www.npl.co.uk/	Oil and gas defects and detection

Essential information for assessment

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Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Investigate in-service and manufacturing defects that can occur in a composite component	Manufacturing and in-service defects	A written report covering in-service and manufacturing defects, how they occur and what the implications are across a range of sectors.
2 Examine defect inspection methodologies (inspection, evaluation and test) and processes for composites	Composite inspection methodologies	A written report covering composite inspection methodologies and processes, which describes the mechanical tests that are carried out to define allowable defects.
3 Investigate the range of repair procedures, their characteristics and applications	Repair procedures and applications	A written report covering repair methods and applications.
4 Carry out processes to inspect and safely repair a polymer composite component, including post-repair inspection	Carry out inspection and repair on a component	A written report, including annotated sketches and photographs, showing learners inspecting and repairing a composite component. Learners' evidence should be supported with observation records.

Assessment guidance

Learning outcome 1 – Manufacturing and in-service defects

For Distinction standard, learners will compare a comprehensive range of defects that can occur during manufacturing and in-service use and explain how they typically occur. They will discuss the implications of these defects across a range of sectors such as aerospace, automotive, construction, renewables and oil and gas. For example, how a void in aerospace could ground a component, or how a void in the marine sector could cause osmosis, etc.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For Merit standard, learners will compare a comprehensive range of manufacturing and in-service defects and how they typically occur. They will cover the majority of the defects listed in learning outcome 1.

Overall, the evidence should be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will outline some manufacturing and in-service defects and how they typically occur.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor technical errors.

Learning outcome 2 – Composite inspection methodologies

For Distinction standard, learners will investigate the standards used for defect inspection across a range of sectors. These will include British and International Standards available for the test methods, as well as company standards. They will acknowledge the qualifications required for testing personnel to enable them to meet the recognised standards.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For Merit standard, learners will detail and compare non-destructive inspection techniques, including key costs, skill levels, and typical applications across the sectors of aerospace, marine, automotive, renewables, construction and oil and gas. Learners will detail how these inspections are carried out to defined requirements and how the data is recorded.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will describe non-destructive inspection techniques, including key costs, skill levels, and typical applications across the sectors of aerospace, marine, automotive, renewables, construction and oil and gas. For P3, learners will describe the mechanical test methods used on composites and how they define allowable defects for components.

Overall, the explanations will be structured logically, although basic in parts, and they may contain minor technical errors.

Learning outcome 3 – Repair procedures and applications

For Merit standard, learners will be given a damaged composite component and will need to analyse what inspection techniques will be the most appropriate to use on the component to determine the extent of the damage. Learners will then discuss a selection of repair techniques that may be suitable and justify their selected choice for repairing the component. They will then discuss which inspection technique they would select to check the effectiveness of the repair method, post-repair.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will be given a damaged composite component and will need to explain what inspection techniques will be the most appropriate to use on the component to determine the extent of the damage. Learners will then discuss a selection of repair techniques that may be suitable for repairing the component. For P5, learners will provide in their evidence the safety procedures and precautions that will be adhered to when carrying out a patch and a non-patch repair to composite components. This will include the appropriate personal protective equipment (PPE) to be used during the preparation of the repair, and using the material safety data sheet (MSDS) for the materials when carrying out the repair.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor technical errors.

Learning outcome 4 – Carry out inspection and repair on a component

For Distinction standard, learners will show in their evidence that they have worked safely, accurately and effectively to inspect and repair a composite component. An assessment of effectiveness might include whether learners worked methodically, skilfully and confidently during the practical phase of the assessment to ensure that the processes were carried out using best practice techniques to produce a good-quality, reliable result, free of flaws. Learners' evidence will also show that they were able to refine the processes as they worked to help ensure they were as safe, accurate and effective as possible. Learners will have selected an appropriate pre- and post-inspection technique to check the extent of the damage and the effectiveness of the repair.

Overall, the evidence will be presented clearly and in a way that would be understood by a third party who may or may not be an engineer.

For Merit standard, learners will show in their evidence that they have worked safely and accurately to inspect and repair a composite component. An assessment of accuracy might include measuring component dimensions once the repair has been carried out to ensure it is consistent and within design tolerances. Learners' evidence will show they have worked safely and accurately to repair the component and have carried out a suitable post-repair inspection.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will show in their evidence how they carried out the safe inspection and repair of a composite component. They will provide a detailed explanation of the choice of repair method and provide evidence of the safety precautions taken. Learners will demonstrate carrying out damage assessment, damage removal and repair processes and explain the safety precautions taken. For P5, learners will explain the procedure and safety precautions for both patch and non-patch repairs to composite components.

Overall, the evidence will be structured logically. It may be basic in parts, for example not recording all of the steps of the processes being carried out, and may contain technical inaccuracies or omissions, such as the occasional use of non-technical language.

Unit 9: Composites Engineering Project

Level: 3

Unit type: Optional

Assessment type: Internal

Guided learning hours: 120

Unit introduction

In the modern world, engineers and technicians are often involved fully or in part with identifying problems and finding suitable solutions. These engineering problems may range from a very large project such as designing and building an aircraft wing, to smaller projects such as designing and producing a new golf club. No matter how large or small, these problems need to be project managed in order to find engineered solutions. This unit will give learners opportunities to present their own solutions to engineering projects, and will enable them to feel confident in carrying out project work within their chosen engineering discipline at the technician level.

A holistic approach is required for this unit, which includes material choice and appropriate processes. Therefore, this unit aims to integrate the knowledge and skills that you have gained throughout the foundation programme of study, into a major piece of work that reflects the type of performance expected of a composites engineering technician. The project is intended to develop your ability to identify and plan a course of action and follow this through to produce a viable solution/outcome to an agreed specification and timescale.

The end result of the project will be a composites product but more importantly it will also be the development of your ability to articulate the process or produce a modification to an existing process or product. As in the real world, the outcome of the project and its presentation are very important, although this project is also about developing the process skills necessary to carry out the project. Throughout the project, you will need to apply and demonstrate the technical skills developed in the other units in the qualification with a strong emphasis on health and safety matters.

Learning outcomes

In this unit you will:

1 Investigate a composites engineering project

2 Develop project-management processes and a design solution for the composites engineering project as undertaken in industry

3 Undertake the solution for a composites engineering project and produce a composites part.

Content

What needs to be learned
Learning outcome 1: Investigate a composites engineering project
Project life cycle An approach to a project life cycle is to split a project into the following four stages: • initiation, to include identifying a problem, research and clarification of a problem, establishing key design features of possible solutions and constraints, idea generation and a feasibility study • planning and design, to include resource and time planning for the chosen solution and creating a design based on the customer's requirements • implementation, to include carrying out project processes to develop the solution while controlling the project by monitoring it against the plans and managing risks and issues • evaluation, to include reviewing the outcome of the project, e.g. whether the customer requirements were met, whether the project was delivered on time and to budget, and how the project was delivered to the given theme or specification. **Project idea generation and solution development** Identification of a suitable problem, perhaps based on a theme, and creation of alternative solutions, including: • researching a given project theme or initial idea and identifying problems to be solved using tools, e.g. the internet, journals, databases, libraries, publicly available company information • creativity tools to solve problems, e.g. rewording problems, challenging assumptions, thinking in reverse, mind mapping, drawing a diagram, group discussion, brainstorming and Edward de Bono's Six Thinking Hats® • a specification that scopes out alternative technical solutions, using outline information to define what possible, as yet undesigned, products, systems or processes are intended to contain and do. The specification could include: ○ graphic solutions, e.g. sketches, diagrams, photographs and storyboards ○ an outline of the required processes, e.g. mould tools, hand tools, equipment, assemblies, high-level flow chart ○ an outline of costings, e.g. spreadsheet, material cost, budgets ○ initial technical information, e.g. approximate mass, approximate volume, suggested materials, outline performance parameters.

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Feasibility study of solutions

Criteria to determine the feasibility of different solutions to a problem, including the potential:

- size and complexity of the problem to be solved
- size of the benefit and performance improvement, e.g. how well a solution solves a problem
- cost and time required to develop each solution, available time, available budget or expertise required to develop a solution
- risks in developing a solution, e.g. unknowns; unproven technology; equipment; time and cost of sustainability, e.g. environmental impact of mass production, waste material, choice of materials, recycling
- legal constraints, e.g. the Data Protection Act 1988 and 2003, Health and Safety at Work etc. Act 1974 or other relevant international equivalents.

Selection of the proposed solution:

- objective testing
- design analysis, e.g. iterative steps, feasibility assessment.

Learning outcome 2: Develop project-management processes and a design solution for the composites engineering project as undertaken in industry

Planning and monitoring project-management processes

Tools to plan and monitor a project:

- resource plan, to include the internet, humans, peers, books and equipment
- time plan, to include a Gantt chart and critical path analysis to set priorities for different activities
- project contingency, e.g. an amount of time or additional budget that is included in the plan to manage unforeseen events
- project constraints, including time, budget, scope, sustainability, ethics and legality
- scheduled and frequent monitoring and management of the project, including:
  - logbook of problems and solutions, technical support, progress, discussions, group activities and development iterations
  - progress against the plan, project milestones, modifications
  - teacher monitoring, peer reviews.

Risk and issue project-management processes

- The purpose of risk and issue management:
  - avoiding 'crisis management'
  - improving the probability of success and increasing competitive advantage.
- A risk is an event that adversely impacts on the project processes or outcome, and an issue is a future event that could adversely or positively impact project processes or outcome.
- Risk and issue measures, including:
  - risk and issue severity = low, medium, high and extreme
  - probability of occurrence = unlikely, likely and very likely
  - expected project impact = minor, moderate and major.
- The risk or issue severity = probability of the occurrence × expected impact on the project, e.g. on the customer's requirements, delivery to time and to budget.
- The resultant risk and issue severity is illustrated in the following matrix:

Probability of threat occurring	Very Likely	Medium	High	Extreme
	Likely	Low	Medium	High
	Unlikely	Low	Low	Medium
		Minor	Moderate	Major
	Expected impact on the project			

Risks and issues should be assessed throughout the delivery of the project, and medium-, high- and extreme severity risks and issues should be managed.

- Management of risks and issues (mitigation), including:
  - prevention (to eliminate the threat of a risk occurring)
  - reduction (to reduce the likelihood of a risk occurring or to reduce the impact of a risk or issue)
  - acceptance (to do nothing about a risk or issue) or transference (to transfer the risk to a third party).
- Allowing contingency in the plans provides some flexibility in the event that risks and issues occur.

Technical specification

- Technical specification for the chosen product being developed, e.g. function and features, interfaces (physical, software, human and electrical/electronic), materials, tolerances, standards, security, environmental considerations and sustainability, operational conditions, process capability, reliability, capacity (current and future), maintenance and performance.

Design information

Tools to design a solution to the problem:

- engineering drawings; computer-aided design (CAD), e.g. 3D, 2D and diagrams; physical modelling, e.g. 3D rapid prototyping (also known as 3D printing or additive manufacturing), mock-ups in wood, cardboard and modelling material
- processes or computer program, e.g. detailed flow chart(s), planning, operation sheets
- documents, e.g. tables, formulas, description and record of ergonomic analysis
- safety and sustainability considerations, including:
  - regulations, e.g. health and safety legislation relevant to the specialist engineering sector
  - demand and costs, e.g. possible demand, material costs, manufacturing costs
  - culture, e.g. beliefs, laws, customs. Test plans to relevant British Standard (BS) or International Standard (IS) where appropriate, e.g. destructive and non-destructive test inspection methods and data (normal, extreme and erroneous).

Learning outcome 3: Undertake the solution for a composites engineering project and produce a composites part
Produce a mould tool • Select materials and a process to effectively and efficiently produce a composites mould tool. Consider the geometrical effects of component design on part demoulding, male and female moulds, plug materials and construction, mould materials and construction. • Consider costs, e.g. raw materials; labour; capital equipment; overheads; effects of design decisions on life cycle costs, tooling, manufacturing processes; finishing. • Implement: specify different types of matrix and reinforcements and select appropriate materials. • Troubleshooting methods to resolve problems, e.g. expected behaviour, half-split, cause and effect, 5 Whys. **Produce a composites component** • Selection of the key manufacturing processes and materials, e.g. layup preparations; workshop considerations; release agents; gel-coats; vacuum bagging; breather fabrics; release fabrics; consumables, peel plies, bagging films; quality escapes, e.g. bridging, vacuum integrity; processing requirements, e.g. autoclave, out-of-autoclave; clean room and storage conditions. • Checking solutions: use of metrology and NDT procedures to check validity and quality of the product made. **Demonstration of relevant behaviours** Relevant behaviours include: • time planning and management to complete all the different activities within an appropriate timeframe and in an appropriate order • communication and literacy skills to follow and implement instructions appropriately, interpret documentation and communicate effectively with others in writing and verbally • commercial and customer awareness to ensure the product, process or system is fit for purpose and meets the brief • observable emotions linked to successes and issues during the project development, including personal successes and issues as well as attitudes and behaviour • individual support required to complete the project, e.g. practical support, academic support, external support.

Present a solution to the problem

- Deliver a presentation to a small group (peer group, tutors); use of preparation techniques, presentation styles and techniques; preparation and use of visual aids, e.g. overhead transparencies, software packages and projectors, charts, models, video/DVD clips.
- Collate a project portfolio that includes:
  - thematic title and/or initial idea
  - research and clarification of the problem
  - possible solutions and constraints
  - initial specification of alternative technical solutions
  - feasibility study
  - technical specification
  - project-management documents, including plans and a risk and issues log
  - logbook of events, e.g. diary, outline sketches, notes, records
  - design documents, e.g. sketches, engineering drawings, simulation and flow charts
  - artefacts for a product, service or process, e.g. prototype product, experiment process demonstration
  - test documentation, e.g. results, video, customer feedback and photographs
  - peer reviews and tutor monitoring
  - conclusions on the success of the solution against the project theme and initial idea.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Investigate a composites engineering project		
P1 Research a composites engineering problem based on a given theme and scope out at least three alternative solutions.	M1 Assess consistently at least three solutions to a composites engineering problem on a given theme and recommend a preferred solution.	D1 Evaluate, using language that is technically correct and of a high standard, at least three realistic solutions to an engineering problem on a given theme and justify a preferred solution.
P2 Outline at least three alternative solutions to a composites engineering problem and select a preferred solution.		
Learning outcome 2: Develop project-management processes and a design solution for the composites engineering project as undertaken in industry		
P3 Implement project-management processes, including planning, monitoring and risk and issue management.	M2 Implement project-management processes, including detailed planning and monitoring and proactive risk and issue management.	D2 Optimise the project-management processes and design solution while allowing for reasonable contingency and considering constraints.
P4 Produce the technical specification for a solution to an engineering problem.	M3 Design a coherent solution, considering alternative approaches.	
P5 Produce design documentation to detail the solution, including a test plan and taking account of sustainability.		

Learning outcome 3: Undertake the solution for a composites engineering project and produce a composites part.		
P6 Produce a solution safely using project-management processes while recording progress.	M4 Perform effective project-management processes while justifying refinements and demonstrating effective behaviours consistently, to develop a solution that is fit for audience and purpose.	D3 Optimise the project-management processes to develop a solution that is fit for audience and purpose while anticipating and resolving risks and issues, demonstrating behaviours to a professional standard.
P7 Perform relevant behaviours effectively while developing a solution safely.		
P8 Prepare and deliver a presentation to a small group outlining the project development from the initial research through to the final solution.		
P9 Collate a project portfolio that documents and records project management processes throughout the project life cycle.		

Further information for tutors and assessors

Resources

The special resources needed for this unit include a wide variety of physical resources, dependent on the type of composite project that learners pursue. Many of these resources are detailed in the other units in the qualification.
Learners also need access to workshops, laboratories and specialist software and databases.

Suggested reading

Textbooks

Cooke E et al – *Edexcel BTEC Level 3 National Engineering Student Book* (Pearson, 2010) ISBN 9781846907241

Lock D – *Project Management* (Gower Publishing, 2003) ISBN 9780566085512

Melton T – *Project Management Toolkit: The Basics for Project Success* (Butterworth-Heinemann, 2007) ISBN 9780750684408

O’Connell F – *What You Need to Know About Project Management* (Capstone, 2011) ISBN 9780857081315

Smith N J – *Engineering Project Management* (Blackwell Publishing, 2007) ISBN 9781405168021

Websites

www.engineeringtoolbox.com/ndt-non-destructive-testing-d_314.html	Website describing appropriate non-destructive testing techniques
www.mindtools.com/pages/article/newTMC_5W.htm	Website detailing 5 Whys analysis for identifying the root causes of problems

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Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Investigate a composites engineering project	Investigate a composites engineering project	Research evidence, investigating an initial idea and possible solutions, scoping out alternative technical solutions and completing a feasibility study report of the possible solutions.
2 Develop project-management processes and a design solution for the composites engineering project as undertaken in industry	Implement project-management processes to develop a solution for a composites engineering project	Evidence of applying project-management processes, such as planning during the design of a solution. Also, the development of a technical specification that may include design documentation, such as orthographic projections of the chosen solution.
3 Undertake the solution for a composites engineering project and produce a composites part.	Development and testing of a project solution	Evidence of applying project-management processes, such as project monitoring, and applying relevant behaviours during the development and testing of a solution. A portfolio of evidence generated while completing the composite engineering project, reviewing the processes and reflecting on own performance. A formal presentation given to their peer group, reviewing the project and reflecting on their own performance.

Learning outcome 1 – Investigate a composites engineering project

For Distinction standard, learners will produce research evidence containing a series of at least three possible solutions to the given theme or initial idea. The research evidence and alternative solutions to a composites engineering problem will be realistic, accurate and concise. For example, a project to design and manufacture a scale model (1 : 43) body shell of a Formula 1® racing car will involve researching computer-aided design (CAD)/computer-aided manufacturing (CAM) processes, as well as manufacturing the model using the resin transfer moulding (RTM) process. Also, the CAD/CAM processes will be appropriate to the task, and problems relating to its integration with the moulding processes will be considered and resolved. Learners will provide an outline specification of the solution to include sketches, required processes, outline costs and technical information. The feasibility study will be fully supported by research applied consistently across each solution. A range of criteria will allow good justification for the preferred solution to be presented. For example, the outline sketches and specification of the model body shell will be assessed against the availability and suitability, in terms of size and capability, of the computer numerical control (CNC) machines used to create the mould plug and the RTM machine at the centre. Also, costs will be calculated and compared to the budget allocated by the centre. Overall, the evidence, including the research and feasibility study, will be easy to read and understand by a third party who may or may not be an engineer. It will be structured logically, use correct technical engineering terms and have a high standard of written language. Consideration will be given to the number of possible design iterations required while developing the solution.

For Merit standard, learners will produce research evidence covering at least three possible solutions to an engineering problem. All solutions will be investigated consistently (to a similar breadth and depth) but one solution may not be realistic. A high-level specification scoping out alternative technical solutions to the problem will also be given. The feasibility study will assess each of the alternative solutions in turn. The study will be supported by research evidence of consistent breadth and depth across the three solutions. Sufficient criteria will be used in the assessment to make an informed rationale for the preferred solution. For example, for the manufacturing cost (including materials and tooling) the model body shell will be estimated and compared against the budget. Also, the appropriateness of the centre’s resources, including CAD systems, CNC machines and an RTM machine, will be assessed against their suitability to manufacture the model plug for the body shell, for example in terms of size. Overall, the evidence will be structured logically, be technically accurate and easy to understand. However, learners may not appreciate the number of design iterations required to scope out three different solutions.

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For Pass standard, learners will produce research evidence covering at least three possible solutions to an engineering problem. The research will be patchy in some areas and it may not support all of the solutions given. At least one solution may not be realistic. For example, the CAD and CAM process may not be totally appropriate for the model body shell of a Formula 1® racing car as it does not consider the working envelope of the CNC and RTM machine. A high-level specification scoping out alternative technical solutions to the problem will be produced. The feasibility study will assess each of the alternative solutions in turn. The study will be supported by the research although the depth of evidence will be inconsistent across the three solutions and the study will not cover enough criteria to make an informed decision on which solution to develop. A preferred solution will be selected. For example, for the model body shell learners will have taken into consideration the suitability of the human resources and materials and the capability of some machines, but will not have estimated the costs. Overall, the evidence will be structured logically, although basic in parts, and may contain minor technical inaccuracies relating to engineering terminology.

Learning outcome 2 – Implement project-management processes to develop a solution for a composites engineering project

For Distinction standard, learners will produce an optimised project time and resource plan, outlining the critical path and suitable milestones and breaking down the activities in an appropriate way given the constraints, allowing a reasonable contingency. Most time and resource estimates will be reasonable and consideration will be given to optimising the plan so that it can be implemented in an efficient and effective way. Throughout the project, progress will be monitored and risks and issues managed by anticipating some problems before they become issues, and categorising risks and issues appropriately. The technical specification will detail the customer's operational requirements that link together to create a functioning and coherent solution given the known constraints. For example, the model body shell of a Formula 1® racing car will be RTM formed, and details of appropriate mould materials, typically aluminium or wood, and working tolerances, such as draft angles, will be provided to an international standard. The design evidence, which may be included in the technical specification, will provide details of the proposed solution, and appropriate tools will be used given the nature of the product, system or process. The design evidence will consider sustainability and contain appropriate detail. The solution will be optimised by iteration, within given constraints, by considering the merits of alternative approaches to achieving the chosen solution. For example, the CNC program for manufacturing a mould plug for a model body shell will be optimised by manual coding to improve the post-processed program, which may be inefficient if, for example, it is too long as canned cycles were not used. An outline test plan with parameters that demonstrate a fully functioning product, system and process will be given. Overall, the evidence will be structured logically, be technically accurate and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will produce a detailed project time and resource plan, outlining the critical path and suitable milestones and breaking down the activities in an appropriate way. Most time and resource estimates will be reasonable. For example, the estimated start and finish times to produce CAD drawings and use CNC and RTM machines to manufacture a model body shell will be realistic. Project-monitoring documentation will also be prepared. Risk and issue management processes will be set up, and major risks and issues will be recorded and proactively managed with effective mitigation to prevent some major risks becoming issues. The technical specification will detail the customer's operational requirements that link together to create a functioning and coherent solution. For example, to manufacture a model body shell to a scale of 1 : 43 will be necessary to meet the customer's requirements. The design evidence, which may be included in the technical specification, will provide details of the proposed solution, and appropriate tools will be used given the nature of the product, system or process. The design evidence will consider sustainability and contain appropriate detail while considering the merits of alternative approaches to achieving the chosen solution. For example, one alternative approach in a CNC program used to manufacture a mould plug for a model body shell would be to use canned cycles.

An outline test plan with parameters that demonstrate a fully functioning product, system and process will be given. For example, the inspection and proving methodology for the CNC program used to manufacture a mould plug for a model body shell will be given, including dry runs, simulations, mechanical inspection methods and documentation for the mould and final product, complete with relevant tolerances. Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will produce evidence containing a project time and resource plan outlining the critical path. The plan will be sufficiently detailed to track the project, although some tasks may be omitted and the time and resource estimates for several tasks may be extreme, making them unrealistic. For example, the time estimated to produce the CAD drawings for the model body shell of a Formula 1® racing car may be specified as a couple of hours when a realistic estimate would be two days to complete and edit the drawings. Project-monitoring documentation will also be prepared. Risk and issue management processes will be set up and major risks and issues will be recorded, although actions taken to prevent risks becoming issues are unlikely to be implemented and/or the mitigating actions will not be successful. The technical specification will outline operational customer requirements that may not link together to create a functioning and coherent solution. For example, the manufacture of a model plug for a body shell may include the tooling required for the CNC machine but not other processes. The design evidence, which may be included in the technical specification, will provide details of the proposed solution and appropriate tools will be used given the nature of the product, system or process. The design evidence may lack appropriate detail to implement the solution and some consideration for sustainability will be made. For example, the material used for proving the CNC program to manufacture a mould plug for the body shell may be wax as it can be recycled easily. An outline test plan with parameters that demonstrate a limited understanding of a functioning product, system and process will be given. For example, no inspection methodology will be specified for the CNC program used to manufacture a mould plug of the model body shell, such as undertaking dry runs and simulations. However, consideration of the final product with relevant tolerances will be given. Overall, the design will be structured logically and will be generally fit for purpose given the constraints. However, it may be basic in parts, contain minor inaccuracies such as rounding errors or inconsistent units, and some engineering terminology may be inaccurate.

Learning outcome 3 – Development and testing of a project solution

For Distinction standard, learners will produce evidence showing how the project solution was developed effectively and efficiently using project-management processes to produce a product/service, system or process. The implementation of tasks will be structured and carried out in an appropriate order. There will also be evidence of refinements being made to the solution during the process to optimise it. For example, during the moulding process for a model body shell of a Formula 1® racing car, bubbles may form within the skin of the polymer creating an undesirable finish. The solution to the issue would be to degas the polymer thoroughly before moulding the body shell. Appropriate tests will be completed on the product, system and process and against the test plan. For example, final measurements will be taken on the model body shell. If some of the measurements are marginally above learners' permitted tolerance they may decide that the product is fit for purpose and audience or they may rework the mould. Relevant behaviours will be applied to a professional standard throughout the process. For example, learners will anticipate risks before they arise, taking appropriate action to resolve risks and issues in a structured way and acting appropriately at all times in the workshop.

Overall, the final solution will be presented in both a concise portfolio of evidence and a formal presentation to their peer group that is structured logically. Conclusions will demonstrate that the solution is fit for audience and purpose. Any minor inaccuracies, such as rounding errors or follow-through errors, will occur infrequently if at all. Units and engineering terminology will be accurate and used appropriately throughout. For example, all drawings for the model body shell will be dimensioned in millimetres, with tight and reasonable tolerances. If errors are identified, then learners will identify the source of the error, for example a programming mistake, and take corrective action.

For Merit standard, learners will produce evidence detailing the project-management processes, including monitoring progress and risk and issue management, that were used effectively during the development of the product, process or system. The implementation of tasks will be structured and carried out in an appropriate order. Any changes made to the solution during the process will also be justified and risks and issues managed. For example, if the final model body shell contained resin-rich areas, learners will identify poor layup skills or a severe geometry change in the mould and justify a solution to the issue. Appropriate tests will be completed on the product, system and process and against the test plan. These will demonstrate that the final solution is fit for audience (the end users) and purpose (functionality and technical specification). For example, the output of a scale-model body shell of a Formula 1® racing car will be dimensionally accurate as demonstrated by the inspection evidence that may cover the final product and the mould. Relevant behaviours will be effectively applied throughout the process. For example, learners will take the initiative to resolve issues as they occur, tracking the project and undertaking the project in a structured way. Overall, the final solution will be presented in both a portfolio of evidence and formal presentation to their peer group that is structured logically. Conclusions will demonstrate that the solution is fit for audience and purpose. It will include justification of any improvements to the processes and behaviours that could be applied next time. However, the evidence may contain minor inaccuracies, such as rounding errors or a limited number of follow-through errors. Units and engineering terminology will be accurate and used appropriately.

For Pass standard, learners will produce evidence detailing the project-management processes, including monitoring progress, and risk and issue management processes used during the development of a product, process or system. For example, a product could be to produce a model body shell of a Formula 1® racing car. However, the implementation of tasks will be unstructured and may not be carried out in an appropriate order. This will result in some inefficiency and there will be limited evidence of refinements being made to the solution during the process. For example, if the design of the model body shell did not take into account the size of the RTM machine, the CNC-machined mould would not then fit within the working envelope of the machine, resulting in some rework to the mould. Using the test plan, appropriate tests will be completed on the product, system or process. However, the final solution may not be fully fit for the audience (the end users) and purpose (functionality and technical specification). For example, the manufactured model body shell may not conform to the specification due to minor engineering drawing errors that have been compounded by further minor tolerance errors while machining the mould. Relevant behaviours will be applied during the process. For example, learners will take responsibility to carry out processes safely and to submit work on time. Overall, the final solution will be presented in both a portfolio of evidence and formal presentation to their peer group that is structured logically. The conclusion will demonstrate that the solution is generally fit for purpose, given the constraints. However, it may be basic in parts, may contain minor inaccuracies, such as rounding errors or inconsistent units, and the engineering terminology will be limited and may be inaccurate.

Unit 10: Making Composite Parts Using Prepreg Materials

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

Unit introduction

Prepreg processes predominantly use the dexterity of human hands to position and manipulate the material into the mould tool. The hand layup of prepreg material is a cost-effective method for offering the highest quality of component. This labour-intensive approach has led to prepreg laminating becoming a modern craft.

In this unit, you will gain the knowledge and opportunity to produce composite parts ranging from simple to complex using hand layup techniques with prepreg materials. The unit details the importance of every stage of the process and will give you the knowledge they need to make technical decisions.

Working as a composite technician, it is important to understand the fundamentals of prepreg laminating and how material properties can be changed by errors in the process. This unit will help to prepare you for a composite technician apprenticeship, as well as providing essential knowledge for design and manufacturing roles. In addition, the unit will help to prepare you for higher education and progression to other composite courses.

Learning outcomes

In this unit you will:

1 Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used when manufacturing with prepreg

2 Examine the materials and resins (including consumable and ancillary items) used when manufacturing with prepreg and how these affect the processing parameters

3 Examine the layup techniques and the environment required when manufacturing with prepreg, including the health and safety requirements

4 Manufacture a cored item using prepreg materials and carry out a post-manufacture inspection.

Content

What needs to be learned
Learning outcome 1: Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used when manufacturing with prepreg
Typical tooling used in the prepreg manufacturing process • Tooling materials, to include composite and metallic: aluminium, steel, invar, fibreglass, graphite. • Tooling design, to include male, female, single sided, double sided, mandrels and bladders, multi-part, closed tools, press tooling, soluble cores. **Tool care and preparation** • Preparation of a new tool: the use of mould sealers, cleaners and the range of release agents available; compatibility with the resin system. • Tool care: safely removing resin, how to remove and repair small scratches and other minor defects, gel coat defects and wear. **Demoulding techniques** • The effect of tooling design on demoulding, to include sufficient flanges to prevent tool and component damage. • Tools and methods used for demoulding to prevent tool damage, to include wedges and air blowing.
Learning outcome 2: Examine the materials and resins (including consumable and ancillary items) used when manufacturing with prepreg and how these affect the processing parameters
Materials • Storage criteria for prepreg materials, including the recording of outlife. • Storage and transportation of preform prepregs. • Product codes. • Typical materials and areal weights used: UD, woven (twill, satin, scrim), adhesive film. • Core materials: honeycomb, foam. **Processing methods** • Autoclave processing of prepregs: nitrogen versus oxygen atmosphere; consolidation and resin flow; venting; thermocouples; cost, both initial setup and running cost. • Out-of-autoclave prepregs: advantages, disadvantages, applications.

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Resin requirements • Specific processing requirements for a range of resins (epoxy, phenolic, bismaleimide, cyanate esters): pressure, temperature, ramp and cool rates, dwell times. • Curing methods: autoclave, heated tools, oven, press, heat mats, curing lamps, UV curing, microwave curing. • Cure monitoring methods: thermocouple, dielectric. **Consumable materials** • Use of peel ply, release film, breather felt, bagging material, mandrel bags, reusable bags, vacuum tables, flash tape.
Learning outcome 3: Examine the layup techniques and the environment required when manufacturing with prepreg, including the health and safety requirements
Material preparation • Defect identification. • Defrosting requirements. • Cutting and kitting and nesting. • Ply orientation. **Layup methods and environment** • Draping, corners, overlap joins, butt joins, net edges, staggered joins, inserts and fixtures. • Consolidation: hot and cold debulking. • Recording of ply layup. • Clean room environment temperature and humidity control. • Bagging methods: surface bags, envelope bags, pleats and tucks, multi-part envelope bags, internal bagging. Methods for checking vacuum integrity, including allowable losses. **Layup faults** • Bridging – how and why it occurs, how to overcome. • Gapping – when the material weave separates either due to weave style or overworking the material. • Trapped air – must be removed during layup, is not removed on debulk. • Contamination – dirt, moisture, other materials, consumables. • Tack – if resin is tacky then repositioning plies will affect release coating, resin content, or previous ply. **Layup tooling** • Manipulators: types, sizes, material; heat gun/hairdryers – advantages and risks. • Intensifiers, placement jigs, laser placement.

Health and safety issues

- Carcinogenic materials, moving rolls of material, cutting straight edges, hazardous hand tools such as knives and scalpels, material safety data sheet (MSDS).

Learning outcome 4: Manufacture a cored item using prepreg materials and carry out a post-manufacture inspection

Planning

- Plan the work to be carried out using a planning sheet: specify the joint types and locations, cure cycle and health and safety procedures.

Tool selection and preparation

- Select appropriate tooling to produce the item.
- Prepare the tooling appropriately for the resin types and processing requirements.

Materials

- Prepare the materials for manufacture, including defrosting the material, cutting and kitting, recording product codes and dates.
- Select appropriate consumable and ancillary materials.
- Dispose of waste accordingly.

Layup

- Layup the materials according to the planning sheet.
- Select and use appropriate hand tools.
- Bag and prepare for cure.

Processing

- Cure the materials according to the material data sheet.
- Monitor the cure.

Demoulding

- Demould the component safely and without causing mould tool damage.
- Finish the component to remove any sharp edges.
- Clean, check and store the tooling after use.

Inspection

- Check the component and highlight any defects.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used when manufacturing with prepreg		
P1 Describe typical materials used in tooling when manufacturing with prepreg and list their advantages and disadvantages.	M1 Compare the advantages and disadvantages of tooling designs and state typical applications.	D1 Evaluate tooling designs for the manufacture of a hollow prepreg structure.
P2 Describe how to prepare a new mould tool for the application of a prepreg laminate.		
P3 Discuss correct demoulding techniques and the consequences if these are not followed.		
Learning outcome 2: Examine the materials and resins (including consumable and ancillary items) used when manufacturing with prepreg and how these affect the processing parameters		
P4 Describe the typical material reinforcements, the typical resins and the typical core materials used in the prepreg manufacturing process.	M2 Explain autoclave cure cycles and how this varies for different resin systems.	D2 Analyse why cure monitoring is important and compare two methods.
P5 Describe the consumable and ancillary materials used in the prepreg manufacturing process.		

Learning outcome 3: Examine the layup techniques and the environment required when manufacturing with prepreg, including the health and safety requirements		
P6 Describe the layup methods and tools available and the appropriate environmental conditions for prepreg composite laminating.	M3 Explain the common layup faults and how debulking helps with the layup process.	
P7 Discuss the health and safety risks with prepreg laminating.		
Learning outcome 4: Manufacture a cored item using prepreg materials and carry out a post-manufacture inspection		
P8 Write a planning and operation sheet for the manufacture of a prepreg composite component and carry out the post manufacture inspection.	M4 Produce a written technical report of the manufacture of a prepreg composite component, showing full traceability of the process.	D3 Create a presentation showing the process carried out to produce a prepreg component and highlight where refinements could have been made.

Further information for tutors and assessors

Resources

The special resources needed for this unit are facilities, or access to facilities, that enable the manufacture of composite components.

Suggested reading

Textbooks

Campbell F C – *Manufacturing Processes for Advanced Composites* (Elsevier Science, 2003) ISBN 9781856174152

Dorworth L C, Gardiner G L and Mellema G M – *Essentials of Advanced Composite Fabrication & Repair* (Aviation Supplies and Academics, Inc., 2009) ISBN 9781560277521

Strong B – *Fundamentals of Composites Manufacturing: Materials, Methods, and Applications* (Society Manufacturing Engineers, 2007) ISBN 9780872638549

Websites

www.gurit.com/-/media/Gurit/Datasheets/guide-to-composites.ashx	A comprehensive guide to composites and structures
https://netcomposites.com/guide-tools/guide/manufacturing/prepreg-moulding/	Prepreg moulding overview

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used when manufacturing with prepreg	Tooling materials, designs, preparation and care for manufacturing with prepreg	A written report that explores the tooling materials, designs, preparation and care used in the prepreg manufacture process.
2 Examine the materials and resins (including consumable and ancillary items) used when manufacturing with prepreg and how these affect the processing parameters	Materials, resins and processing parameters used when manufacturing with prepreg	A written report that looks at the materials and resins used in prepreg manufacturing and the consumable and ancillary materials used to enable the process. Graphical displays can be used to explain autoclave and cure monitoring theory.
3 Examine the layup techniques and the environment required when manufacturing with prepreg, including the health and safety requirements	Layup techniques, environmental conditions and health and safety requirements when manufacturing with prepreg	A written report that describes the layup process, the required environmental conditions and the health and safety considerations.
4 Manufacture a cored item using prepreg materials and carry out a post-manufacture inspection	Manufacture of a cored item	A presentation and a written report to evidence the work carried out to produce a complex prepreg item. Learners' evidence could be supported with observation records.

Assessment guidance

Learning outcome 1 – Tooling materials, designs, preparation and care for manufacturing with prepreg

For Distinction standard, learners will evaluate how the use of soluble cores, inflatable mandrels and multi-part tools can all be used to achieve a consolidated hollow structure. They will discuss the advantages and disadvantages of each method and include an evaluation of surface finish with each method.

Overall, the evidence will be logically structured, technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will show the advantages and disadvantages of the tooling designs in the learning outcome. They will include witness lines on multi-part tools, a comparison of the benefits of male tools and female tools and the manufacturing issues that can occur using these designs. They will highlight typical applications for each of the tool designs.

Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will compare different materials used in tooling for prepreg manufacture. They will consider the coefficient of thermal expansion (CTE), the temperature range, the number of cycles and resin compatibility of the material. This will build on the work covered in learning outcome 2 of *Unit 5*, and make it process specific. For P2, learners will describe how a new tool needs to be cleaned and sealed, using appropriate treatments for the tool material. They will describe how release agents are selected, based on the tool material, the resin and the processing parameters. For P3, learners will discuss how demoulding a part can cause damage to both the tool and the component if correct techniques are not followed. Learners will highlight the importance of using 'soft' tools as wedges for prising components out of tools.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor technical errors.

Learning outcome 2 – Materials, resins and processing parameters used when manufacturing with prepreg

For Distinction standard, learners will analyse the importance of cure monitoring and how it is essential in an autoclave cure. They will compare the method of temperature measurement and viscosity measurement and discuss the advantages and disadvantages of both. They will include the importance of monitoring for exotherm and how this could affect the composite component.

For Merit standard, learners will explain an autoclave cycle graphically, including ramp rates, dwell times, cure dwell and pressure. They will explain how the viscosity of the resin varies during cure and where the gel point occurs during the cycle. They will discuss how the cycle varies for different resin types and when venting of the autoclave is used. They will also explain a typical post-cure and what it achieves.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the typical reinforcements used in prepreg, including the range of areal weights. They will compare typical resins used in prepreg and typical core materials used when manufacturing with prepreg. They will explain how prepreg materials are stored and controlled, including outlife monitoring. They will explain the range of consumable and ancillary materials used during the process and the different vacuum bagging techniques available.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor errors.

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Learning outcome 3 – Layup techniques, environmental conditions and health and safety requirements when manufacturing with prepreg

For Merit standard, learners will explain the common layup faults, how they occur and how to prevent them. They will discuss why debulking is important, and why temperature is sometimes used in the process. They will acknowledge that debulking is a consolidation method and does not remove air or prevent bridging.

Overall, the evidence will be logically structured, technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the layup techniques, including the correct defrosting methods for prepreg, cutting, kitting, nesting and orientating the material; and draping, tailoring and consolidating the layup. They will describe the tools used to assist the process, including positioning aids for the correct location of plies. They will describe the ideal environmental conditions for prepreg laminating and the errors that can occur if they are not adhered to. They will discuss the health and safety risks with prepreg laminating, and must include material safety data sheets (MSDS), carcinogenic materials, lifting of prepreg rolls and cutting of material.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor errors.

Learning outcome 4 – Manufacture of a cored item

For Distinction standard, learners will give a technical presentation of their manufacturing process and highlight where refinements could have been made. The presentation will cover the manufacturing process, including tool preparation, material preparation, planning sheet, layup techniques, consumables and bagging, cure cycle, trimming and finishing, and post-manufacture inspection.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will produce a technical report that covers the manufacturing process, including tool preparation, material preparation, planning sheet, layup techniques, consumables and bagging, cure cycle, trimming and finishing, and post-manufacture inspection.

Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will produce a planning and operation sheet for their manufacturing process using prepreg materials. The sheet will include tool preparation, material preparation, layup techniques, consumables and bagging, cure cycle, trimming and finishing, and post-manufacture inspection.

Overall, the planning sheet will be structured logically, although basic in parts, and may contain minor errors.

Unit 11: Wet Layup Techniques

Level: 3

Unit type: Optional

Assessment type: Internal

Guided learning hours: 60

Unit introduction

Wet layup (wet laminating) is a widely used technique for making composite parts. It is often thought of as a technique for making low-cost composites or small production runs of parts, however the technique can nevertheless produce excellent quality, high-performance products.

In this unit, you will understand how to produce composite parts ranging from simple to complex using wet layup techniques. It details the importance of every stage of the process and will equip learners with the knowledge to make in-process technical decisions. A holistic approach is required, which includes an understanding of wet layup materials, tool care and preparation, material choice and an appropriate process.

Learning outcomes

In this unit you will:

1 Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with wet lay manufacturing

2 Examine the materials and resins (including consumable and ancillary items) used in wet lay manufacturing and how these affect the processing parameters

3 Examine the layup techniques and the environment required to carry out the wet lay manufacturing process, including the health and safety issues

4 Carry out the wet lay manufacturing process to produce a complex item, including a post-manufacture inspection.

Content

What needs to be learned
Learning outcome 1: Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with wet lay manufacturing
Typical tooling used in the wet lay manufacturing process • Tooling material, to include wood, GRP, MDF board, chipboard, plywood, solid wood, hard shell plaster, metal silicone rubber compounds, prototyping board or polyurethane casting material composite, metal. • Tooling design, to include male, female, single sided, double sided, multi-part, flange sizes, oversizing to allow for part shrinkage. **Tool care and preparation** • Preparation of a new tool: the use of mould sealers, cleaners and the range of release agents and waxes commonly used; compatibility with resin system. • Tool care: safely removing resin; how to remove and repair small scratches and other minor defects; gel coat defects and wear.
Learning outcome 2: Examine the materials and resins (including consumable and ancillary items) used in wet lay manufacturing and how these affect the processing parameters
Materials • Typical materials used: continuous and chopped fibres; woven, knitted, stitched cloths or bonded fabrics, braids; effects of fibre format on resin to fibre ratio. • Cores and inserts: foams, wood and balsa, metallic inserts. • Storage criteria. **Gel coats** • Types, how to apply, number of layers, pigments, additives, flow/top coats. **Resins** • Polyester resins, vinyl esters, epoxies, formulated resin systems; multi-part systems; compatibility with fibres. • Mixing resins: epoxy (hardener), polyester (catalyst), degassing, pot life, gel time, complete cure, post-cure; fibre volume fraction. • Effects of temperature; storage; waste disposal; environmental control; dispensing; mixing. • Additives: accelerators, plasticisers, glass bubbles, inhibitors, pigments, thixotropes. **Consumable materials** • Flash tape, brushes, buckets, rollers, plastic sheeting and other ancillary materials.

Learning outcome 3: Examine the layup techniques and the environment required to carry out the wet lay manufacturing process, including the health and safety issues

Material preparation

- For example: ply overlaps, resin/fibre ratio, thickness effects, cutting kitting and materials preparation, correct handling, storage and usage of materials, workshop layout.

Layup technique and environment

- Wetting out, back-wetting, consolidation, exotherm, emissions, extraction, gel point, fully cured, post-curing, thermal expansion.
- Hand layup, spray layup by brushing into the mould or spraying into the mould, spreading out, interpret layup specifications.
- Environment: temperature range, humidity and control requirements.

Layup faults

- Bridging: how and why it occurs; how to overcome.
- Gapping: when the material weave separates either due to weave style or overworking the material.
- Trapped air: must be removed during layup, is not removed on debulk.
- Contamination: dirt, moisture, other materials, consumables.
- Resin content: too much or too little resin will affect component strength.
- Incorrect mixing: exotherm or incomplete curing.

Tools

- Selecting and using hand tools: short bristled brushes, bristle rollers, roller radius, cutting blades, scissors, roller blade cutters.
- Using equipment: mixing containers, weighing scale or epoxy dispensers, catalyst bottles, mixing sticks or electric mixers, cups.

Health and safety issues

- Material safety data sheet (MSDS), styrene/VOC emissions, skin contamination, fibre and resin allergy, personal protective equipment (PPE).
- Waste disposal and clean-down procedures.

Learning outcome 4: Carry out the wet lay manufacturing process to produce a complex item, including a post-manufacture inspection
Planning • Plan the work to be carried out using a planning sheet: specify gel coat requirements, specify the joint types and locations, the resin type and mix ratios, and the health and safety procedures. **Tool selection and preparation** • Select appropriate tooling to produce the item. • Prepare the tooling appropriately for the resin type and processing requirements. **Materials** • Prepare the materials for manufacture, including cutting and kitting, recording product codes and dates. • Select appropriate consumable and ancillary materials. **Layup** • Layup the gel coat and materials according to the planning sheet. • Select and use appropriate hand tools. • Dispose of waste accordingly. **Processing** • Cure the materials according to the material data sheet. • Monitor the cure for exotherm. **Demoulding** • Demould the component safely and without causing mould tool damage. • Finish the component to remove any sharp edges. • Clean, check and store the tooling after use. **Inspection** • Check the component and highlight any defects.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with wet lay manufacturing		
P1 Describe typical materials used in tooling for wet lay manufacture and compare their advantages and disadvantages.	M1 Compare the advantages and disadvantages of tooling designs and state typical applications.	D1 Evaluate tooling designs for the manufacture of very large wet lay structures.
P2 Describe how to prepare a new mould tool for the application of a wet lay laminate.		
P3 Discuss correct demoulding techniques and the consequences if these are not adhered to.		
Learning outcome 2: Examine the materials and resins (including consumable and ancillary items) used in wet lay manufacturing and how these affect the processing parameters		
P4 Describe the typical material reinforcements, the typical resins and the typical core materials used in the wet lay process.	M2 Explain the different types of resin additives available and their purpose.	D2 Analyse the cure cycle of a wet lay composite and discuss when and why a post-cure would be used.
P5 Describe the application of a gel coat.		

Learning outcome 3: Examine the layup techniques and the environment required to carry out the wet lay manufacturing process, including the health and safety issues		
P6 Describe the layup methods and tools available and the appropriate environmental conditions for wet lay composite laminating.	M3 Explain the common layup faults and the importance of correct measuring and mixing of resins.	
P7 Discuss the health and safety risks with wet lay laminating.		
Learning outcome 4: Carry out the wet lay manufacturing process to produce a complex item, including a post-manufacture inspection		
P8 Write a planning and operation sheet for the manufacture of a wet lay composite component and carry out the post-manufacture inspection.	M4 Produce a written technical report of the manufacture of a wet lay composite component.	D3 Create a presentation showing the process carried out to produce a wet lay component and highlight where refinements could have been made.

Further information for tutors and assessors

Resources

The special resources needed for this unit are facilities, or access to facilities, that enable the manufacture of composite components using wet lay methods.

Suggested reading

Campbell F C – *Manufacturing Processes for Advanced Composites* (Elsevier Science, 2003) ISBN 9781856174152

Dorworth L C, Gardiner G L and Mellema G M – *Essentials of Advanced Composite Fabrication & Repair* (Aviation Supplies and Academics, Inc., 2009) ISBN 9781560277521

Strong B – *Fundamentals of Composites Manufacturing: Materials, Methods, and Applications* (Society Manufacturing Engineers, 2007) ISBN 9780872638549

Websites

www.gurit.com/-/media/Gurit/Datasheets/guide-to-composites.ashx	A comprehensive guide to composites and structures
https://netcomposites.com/guide-tools/guide/manufacturing/wethand-lay-up/	Wet lay moulding overview

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with wet lay manufacturing	Tooling materials, designs, preparation and care for wet lay manufacturing	A written report that explores the tooling materials, designs, preparation and care used in the wet lay manufacture process.
2 Examine the materials and resins (including consumable and ancillary items) used in wet lay manufacturing and how these affect the processing parameters	Materials, resins and processing parameters used when wet lay manufacturing	A written report that looks at the materials, resins and gel coats used in wet lay manufacturing and the consumable and ancillary materials used to enable the process. An in-depth explanation of the different additives available for resins and gel coats.
3 Examine the layup techniques and the environment required to carry out the wet lay manufacturing process, including the health and safety issues	Layup techniques, environmental conditions and health and safety requirements with wet lay manufacturing	A written report that describes the layup process, the required environmental conditions and the health and safety considerations.
4 Carry out the wet lay manufacturing process to produce a complex item, including a post-manufacture inspection	Manufacture of a complex item	A presentation and a written report to evidence the work carried out to produce a complex wet lay item. Learners' evidence could be supported with observation records.

Assessment guidance

Learning outcome 1 – Tooling materials, designs, preparation and care for wet lay manufacturing

For Distinction standard, learners will evaluate how the use of frames and reinforcing structures are used to enable large tools to be manufactured. They will discuss how these tools are moved and how the tool surface is protected and maintained during layup.

Overall, the evidence will be logically structured, technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will show the advantages and disadvantages of the tooling designs in the learning outcome. They will include witness lines on multi-part tools, a comparison of the benefits of male tools and female tools and the manufacturing issues that can occur using these designs. They will highlight typical applications for each of the tool designs. They will discuss oversizing the tools to accommodate resin shrinkage during cure.

Overall, the evidence will be logically structured, be technically accurate and easy to understand.

For Pass standard, learners will compare different materials used in tooling for wet lay manufacture. They will consider the compatibility of the gel coat and resin, thermal expansion, the number of cycles and resin compatibility of the material. This will build on the work covered in learning outcome 2 of *Unit 5*, and make it process specific. For P2, learners will describe how a new tool needs to be cleaned and sealed, using appropriate treatments for the tool material. They will describe how release agents or waxes are selected based on the tool material, the resin and the processing parameters. For P3, learners will discuss how demoulding a part can cause damage to both the tool and the component if correct techniques are not followed. They will highlight the importance of using 'soft' tools as wedges for prising components out of tools and using lifting points for large components.

Overall, the explanations will be logically structured, although basic in parts and they may contain minor technical errors.

Learning outcome 2 – Materials, resins and processing parameters used when wet lay manufacturing

For Distinction standard, learners will analyse the cure cycle of a wet lay component and will include the gel point, hardening stage and full cure. They will discuss the importance of monitoring for an exotherm during the cure process. They will evaluate the use of a post-cure for wet lay components and the effect of this on component strength.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will explain the benefits of different resin additives available, including accelerators, inhibitors, pigments, catalysts, hardeners, glass bubbles and thixotropes.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the typical reinforcements used in wet lay, including the range of areal weights. They will compare typical resins and gel coats used in wet lay and explain how to apply gel coats. They will describe typical core materials used when wet lay manufacturing, and will explain how wet lay materials are stored and why they have a use-by date. They will explain the range of consumable and ancillary materials used during the process and how to prevent exotherms.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor errors.

Learning outcome 3 – Layup techniques, environmental conditions and health and safety requirements with wet lay manufacturing

For Merit standard, learners will explain the common layup faults, how they occur and how to prevent them and why consolidation is important. They will discuss the importance of correct measuring and mixing of resins and the implications for the structure if it is not carried out accurately.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the layup techniques, including cutting, kitting, nesting and orientating the material; mixing resins; and draping, tailoring and consolidating the layup. They will describe the tools used to assist the process, including spray layup and consolidation rollers. They will describe the ideal environmental conditions for wet lay laminating and the errors that can occur if these are not adhered to. They will discuss the health and safety risks with wet lay laminating and must include material safety data sheets (MSDS), styrene exposure, lifting of rolls and cutting of material.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor errors.

Learning outcome 4 – Manufacture of a complex item

For Distinction standard, learners will give a technical presentation of their manufacturing process and highlight where refinements could have been made. The presentation will cover the manufacturing process, including tool preparation, material preparation, planning sheet, layup techniques, consumables and bagging, fibre volume fraction, trimming and finishing, and post-manufacture inspection.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will produce a technical report that covers the manufacturing process, including tool preparation, material preparation, planning sheet, layup techniques, consumables and bagging, fibre volume fraction, trimming and finishing, and post-manufacture inspection.

Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will produce a planning and operation sheet for their manufacturing process using prepreg materials. The sheet will include tool preparation, material preparation, layup techniques, consumables and bagging, fibre volume fraction, trimming and finishing, and post-manufacture inspection.

Overall, the planning sheet will be structured logically, although basic in parts, and may contain minor errors.

Unit 12: Making Composite Parts Using Resin Infusion Techniques (VRTM & RTM)

Level: 3

Unit type: Optional

Assessment type: Internal

Guided learning hours: 60

Unit introduction

The resin infusion (RI) process is a technique that uses vacuum pressure to drive resin into a laminate. These processes offer the benefit of not requiring an expensive autoclave while also being capable of producing large, complex aerospace-grade parts. Products produced using this method vary widely in their application, with parts being used in transportation, wind energy, marine, infrastructure, and aerospace applications.

In this unit, you will gain the knowledge and opportunity to produce composite parts ranging from simple to complex using resin infusion techniques. The unit details the importance of every stage of the process and will equip you with the knowledge to make technical decisions. A holistic approach is required, which includes an understanding of RI layup materials, tool care and preparation, material choice and appropriate process.

Working as a composite technician, it is important to understand the fundamentals of wet lay laminating and how material properties can be changed by errors in the process. This unit will help to prepare you for a composite technician apprenticeship, as well as providing essential knowledge for design and manufacturing roles. In addition, the unit will help to prepare you for higher education and progression to other composite courses.

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Learning outcomes

In this unit you will:

1 Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with the range of resin infusion manufacturing methods

2 Examine the materials and resins (including consumable and ancillary items) used in resin infusion manufacturing and how these affect the processing parameters

3 Examine the layup techniques and the environment required to carry out the resin infusion manufacturing process, including the health and safety issues

4 Carry out the resin infusion manufacturing process to produce a complex item, including a post-manufacture inspection.

Content

What needs to be learned
Learning outcome 1: Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with the range of resin infusion manufacturing methods
Typical tooling used in the resin infusion process • Tooling design to take into account the different infusion processes: to include resin infusion (RI), resin transfer moulding (RTM), light resin transfer moulding (LRTM), vacuum assisted resin transfer moulding (VARTM), high pressure resin transfer moulding (HPRTM), resin infusion under flexible tooling (RIFT). • Tooling, to include composite, metallic, flexible tooling, matched tooling, seals, heating/cooling techniques, space for hosing, tooling design with inlet and outlet points, flanges, flow channels. **Tool care and preparation** • Preparation of a new tool. The use of mould sealers, cleaners and the range of release agents and waxes commonly used. Selection of treatments based on compatibility with resin system and temperature range. • Tool care: safely removing resin, how to remove and repair small scratches and other minor defects, gel coat defects and wear. **Demoulding techniques** • The effect of tooling design on demoulding, to include sufficient flanges to prevent tool and component damage. • Tools and methods used for demoulding to prevent tool damage, to include points, wedges, cranes, lifting points. • Care around seals and catch pots.
Learning outcome 2: Examine the materials and resins (including consumable and ancillary items) used in resin infusion manufacturing and how these affect the processing parameters
Materials • Storage criteria for dry fabrics and resins. • Typical materials used: woven, biax/non-crimp fabrics, preforms; fully 3D woven preforms, thermal preforming, 3D fabrics. • Combined systems such as SPRINT, CAPRI etc. • Core materials: infusion foam, surfaced honeycomb, coremat, balsa. **Resins** • Epoxy, polyester, vinyl ester, phenolic. • Viscosity, additives, degassing, fibre volume fraction. **Adhesive** • Spray or binder: specific to resin type, compatibility with fibre sizing, use and quantities.

Consumables

- Peel ply, release film, breather felt, sealing tape, flash tape, spiral wrap, solid tube, connectors, valves, taps.
- Flow mesh variants and their applications, to include omega channel, VMS2, VAP.
- Bagging methods, to include surface bagging, envelope bag, pleats and tucks, multi-part bags.

Ancillary items

- Resin injection machines.
- Vacuum pumps.
- Heat lamps.
- Pressure transducers.

Infusion strategies

- Linear, radial, multi-point entry, staged entry, Z X Y infusion, vacuum integrity.
- Injection temperature, degassing, resin trap/catch pot, flow channels, resin dams.
- Computer-aided flow modelling.

Learning outcome 3: Examine the layup techniques and the environment required to carry out the resin infusion manufacturing process, including the health and safety issues

Material preparation

- Handling and cutting dry fibres.
- Ply orientation and kitting.
- Preforms.

Layup technique and environment

- Effective use of spray adhesive or binders.
- Draping, corners, overlap joins, butt joins, net edges, staggered joins, inserts and fixtures.
- Consolidation (debulking): hot or cold.
- Hand trimming.
- Environment: temperature, humidity and control requirements.

Layup faults

- Bridging: how and why it occurs; how to overcome.
- Gapping: when the material weave separates either due to weave style or overworking the material.
- Trapped air: when to debulk.
- Contamination: dirt, moisture, other materials, consumables.
- Tack: excessive use of spray adhesive or binders.

Health and safety issues

- Exotherm, styrene emissions, spray adhesive, heavy tooling, rolls of material, hand tools, uncured resin disposal.

Learning outcome 4: Carry out the resin infusion manufacturing process to produce a complex item, including a post-manufacture inspection

Planning

- Plan the work to be carried out using a planning sheet: specify gel coat requirements, specify the joint types and locations, the resin type and mix ratios, the health and safety procedures.

Tool selection and preparation

- Select appropriate tooling to produce the item.
- Prepare the tooling appropriately for the resin type and processing requirements.

Materials

- Prepare the materials for manufacture, including cutting and kitting, recording product codes and dates.
- Select appropriate consumable and ancillary materials.

Layup

- Layup the gel coat and materials according to the planning sheet.
- Select and use appropriate hand tools.
- Use adhesives/binders as necessary.

Processing

- Cure the materials according to the material data sheet.
- Monitor the cure.
- Dispose of waste accordingly.

Demoulding

- Demould the component safely and without causing mould tool damage.
- Finish the component to remove any sharp edges.
- Clean, check and store the tooling after use.

Inspection

- Check the component and highlight any defects.

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
Learning outcome 1: Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with the range of resin infusion manufacturing methods		
P1 Describe typical materials used in tooling for resin infusion manufacture and compare their advantages and disadvantages.	M1 Compare the advantages and disadvantages of tooling designs and state typical applications.	D1 Evaluate the different resin infusion processes.
P2 Describe how to prepare a new mould tool for the resin infusion process.		
P3 Discuss correct demoulding techniques and the consequences if these are not adhered to.		
Learning outcome 2: Examine the materials and resins (including consumable and ancillary items) used in resin infusion manufacturing and how these affect the processing parameters		
P4 Describe the typical material reinforcement, the typical resins and the typical core materials used in the resin infusion process.	M2 Compare the different infusion strategies and their typical applications.	D2 Evaluate different infusion strategies and discuss how computer modelling aids the infusion of large structures.
P5 Explain the consumable and ancillary materials used in RI manufacturing processes.		

Learning outcome 3: Examine the layup techniques and the environment required to carry out the resin infusion manufacturing process, including the health and safety issues		
P6 Describe the layup methods and tools available and the appropriate environmental conditions for resin infusion.	M3 Explain the common layup faults and how debulking helps with the layup process.	
P7 Discuss the health and safety risks with resin infusion.		
Learning outcome 4: Carry out the resin infusion manufacturing process to produce a complex item, including a post-manufacture inspection		
P8 Write the planning and operation sheet for the manufacture of a resin infusion component, including the post-manufacture inspection criteria.	M4 Produce a written technical report of the manufacture of a resin infusion composite component.	D3 Create a presentation showing the process carried out to produce a resin infused component and highlight where refinements could have been made.

Further information for tutors and assessors

Resources

The special resources needed for this unit are facilities, or access to facilities, that enable the manufacture of composite components using resin infusion techniques.

Textbooks

Campbell F C – *Manufacturing Processes for Advanced Composites* (Elsevier Science, 2003) ISBN 9781856174152

Dorworth L C, Gardiner G L and Mellema G M – *Essentials of Advanced Composite Fabrication & Repair* (Aviation Supplies and Academics, Inc., 2009) ISBN 9781560277521

Strong B – *Fundamentals of Composites Manufacturing: Materials, Methods, and Applications* (Society Manufacturing Engineers, 2007) ISBN 9780872638549

Websites

www.gurit.com/-/media/Gurit/Datasheets/guide-to-composites.ashx	A comprehensive guide to composites and structures
https://netcomposites.com/guide-tools/guide/manufacturing/infusion-processes/	Infusion moulding overview

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Learning outcome	Assignment title	Recommended assessment approach
1 Investigate the mould tool materials, tool designs, tool preparation and demoulding techniques used with the range of resin infusion manufacturing methods	Tooling materials, designs, preparation and care for the different resin infusion manufacturing processes	A written report that explores the tooling materials, designs, preparation and care used in the resin infusion manufacture processes.
2 Examine the materials and resins (including consumable and ancillary items) used in resin infusion manufacturing and how these affect the processing parameters	Materials, resins and processing parameters used for resin infusion	A written report that looks at the materials, resins and gel coats used in resin infusion and the consumable and ancillary materials used to enable the process. An in-depth explanation of the different infusion strategies and their typical applications.
3 Examine the layup techniques and the environment required to carry out the resin infusion manufacturing process, including the health and safety issues	Layup techniques, environmental conditions and health and safety requirements with resin infusion	A written report that describes the layup process, the required environmental conditions and the health and safety considerations.
4 Carry out the resin infusion manufacturing process to produce a complex item, including a post-manufacture inspection	Manufacture of a complex item	A presentation and a written report to evidence the work carried out to produce a complex resin infused item. Learners' evidence could be supported with observation records.

Assessment guidance

Learning outcome 1 – Tooling materials, designs, preparation and care for the different resin infusion manufacturing processes

For Distinction standard, learners will evaluate the different resin infusion processes. They will discuss the benefits of each process and highlight a typical application.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will show the advantages and disadvantages of the tooling designs in the learning outcome. They will include a comparison of the benefits of male tools and female tools and the manufacturing issues that can occur using these designs. They will discuss flow channels and seals and where these benefit the resin infusion process. They will highlight typical applications for each of the tool designs.

Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will compare different materials used in tooling for resin infusion. They will consider the compatibility of the gel coat and resin, thermal expansion, the number of cycles and resin compatibility of the material. This will build on the work covered in learning outcome 2 of *Unit 5*, and make it process specific. For P2, learners will describe how a new tool needs to be cleaned and sealed, using appropriate treatments for the tool material. They will describe how release agents or waxes are selected, based on the tool material, the resin and the processing parameters. For P3, learners will discuss how demoulding a part can cause damage to both the tool and the component if correct techniques are not followed. They will highlight the importance of using 'soft' tools as wedges for prising components out of tools and using lifting points for large components.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor technical errors.

Learning outcome 2 – Materials, resins and processing parameters used for resin infusion

For Distinction standard, learners will evaluate the different resin infusion strategies and explore their applications. They will discuss how computer modelling plays an important role in defining infusion strategies for large components.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will compare and describe the different infusion strategies listed in the learning outcomes and state their typical applications.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the typical reinforcements used in resin infusion, including the range of areal weights. They will compare typical resins and gel coats used in resin infusion and explain how to apply gel coats. They will describe typical core materials used with resin infusion and will explain how the materials are stored and why they have a use-by date. They will explain the range of consumable and ancillary materials used during the process and how to prevent exotherms.

Overall, the explanations will be structured logically, although basic in parts, and they may contain minor errors.

Learning outcome 3 – Layup techniques, environmental conditions and health and safety requirements with resin infusion

For Merit standard, learners will explain the common layup faults, how they occur and how to prevent them. They will discuss why debulking is important, and why temperature is sometimes used in the process. They will discuss the implications of overuse of spray adhesive and binders and how this affects the end component.

Overall, the evidence will be logically structured, technically accurate, methodical and easy to understand.

For Pass standard, learners will describe the layup techniques, including cutting, kitting, nesting and orientating the material; mixing resins; preforms; draping, tailoring and consolidating the layup. They will describe the tools used to assist the process, including spray adhesive and debulking. They will describe the ideal environmental conditions for resin infusion and the errors that can occur if these are not adhered to. They will discuss the health and safety risks with resin infusion and must include material safety data sheets (MSDS), styrene exposure, lifting of rolls and cutting of material.

Overall, the explanations will be structured logically, although basic in parts, and may contain minor errors.

Learning outcome 4 – Manufacture of a complex item

For Distinction standard, learners will give a technical presentation of their manufacturing process and highlight where refinements could have been made. The presentation will cover the manufacturing process, including tool preparation, material preparation, planning sheet, layup techniques, consumables and bagging, fibre volume fraction, trimming and finishing, and post-manufacture inspection.

Overall, the evidence will be structured logically, be technically accurate, methodical and easy to understand by a third party who may or may not be an engineer.

For Merit standard, learners will produce a technical report that covers the manufacturing process, including tool preparation, material preparation, planning sheet, layup techniques, consumables and bagging, fibre volume fraction, trimming and finishing, and post-manufacture inspection.

Overall, the evidence will be structured logically, be technically accurate and easy to understand.

For Pass standard, learners will produce a planning and operation sheet for their manufacturing process using prepreg materials. The sheet will include tool preparation, material preparation, layup techniques, consumables and bagging, fibre volume fraction, trimming and finishing, and post-manufacture inspection.

Overall, the planning sheet will be structured logically, although basic in parts, and may contain minor errors.

Unit 13: Mathematics for Engineering Technicians

Level: 3

Unit type: Optional

Assessment type: Internal

Guided learning hours: 60

Unit introduction

One of the main responsibilities of engineers is to solve problems quickly and effectively. This unit will enable learners to solve mathematical, scientific and associated engineering problems at technician level. It will also act as a basis for progression to study other units, both in the qualification, such as *Unit 6: Further Engineering Mathematics*, and at BTEC Higher National level.

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

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

Learning outcomes

In this unit you will:

1 Be able to use algebraic methods

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

3 Be able to use statistical methods to display data

4 Be able to use elementary calculus techniques

Content

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

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

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P1 Manipulate and simplify three algebraic expressions using the laws of indices and two using the laws of logarithms		
P2 Solve a linear equation by plotting a straight-line graph using experimental data and use it to deduce the gradient, intercept and equation of the line	M1 Solve a pair of simultaneous linear equations in two unknowns	D1 Solve a pair of simultaneous equations, one linear and one quadratic, in two unknowns
P3 Factorise by extraction and grouping of a common factor from expressions with two, three and four terms respectively	M2 Solve one quadratic equation by factorisation and one by the formula method	
P4 Solve circular and triangular measurement problems involving the use of radian, sine, cosine and tangent functions		
P5 Sketch each of the three trigonometric functions over a complete cycle		
P6 Produce answers to two practical engineering problems involving the sine and cosine rule		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P7 Use standard formulae to find surface areas and volumes of regular solids for three different examples respectively		
P8 Collect data and produce statistical diagrams, histograms and frequency curves		
P9 Determine the mean, median and mode for two statistical problems		
P9 Determine the mean, median and mode for two statistical problems		
P10 Apply the basic rules of calculus arithmetic to solve three different types of function by differentiation and two different types of function by integration.	M3 Apply the rules for definite integration to two engineering problems that involve summation.	D2 Apply graphical methods to the solution of two engineering problems involving exponential growth and decay, analysing the solutions using calculus.

Further information for tutors and assessors

Resources

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

Suggested reading

Textbooks

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

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

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

Fuller A, Greer A, Taylor G W – *BTEC National Mathematics for Technicians* (Nelson Thornes, 2004) ISBN 9780748779499

Tooley M and Dingle L – *BTEC National Engineering* (Routledge, 2010) ISBN 9780123822024

Websites

www.stemnet.org.uk	Science, Technology, Engineering and Mathematics Network

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, M2	Algebraic Methods	A written activity/test requiring learners to complete five tasks, one for each of the criteria.	A report containing written solutions to each of the five tasks carried out under controlled conditions.
P4, P5, P6, P7	Trigonometric Methods and Standard Formulae	A written activity requiring learners to use trigonometric methods and standard formula to determine areas and volumes.	A report containing the results of calculations and graphic evidence to support the use of trigonometric methods and standard formula for the determination of areas and volumes
P8, P9	Statistical Methods	A written activity requiring learners to collect and display data using different graphical methods, also evaluate the mean, median and mode for a set of discrete and grouped data.	A report containing bar charts, pie charts and the results of calculations to determine the mean, median and mode for a set of discrete and grouped data
P10, M3, D1,	Calculus Techniques	A written activity requiring learners to produce calculations, graphical solutions and analysis to demonstrate use of calculus techniques.	A report containing the solutions to calculations, graphs and analysis of several calculus techniques. Carried out under controlled conditions.

Assessment

The centre's assessment strategy used will need to cover all the learning outcomes and associated pass criteria but not necessarily all the topics included in the unit content.

Criterion P1 could be assessed in the form of a short written test and could possibly also include criterion P3.

P2 could be assessed through an assignment using data from *Unit 56: Electrical and Electronic Principles*, which ideally would be delivered concurrently with this unit.

If this is not possible, learners should be given a range of data sufficient for them to plot the graph and work out the gradient, intercept and the equation. Data forcing them to draw the line of best fit, as opposed to a set of points directly on the graphical line, might be most appropriate.

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

P5 requires learners to sketch each of the three trigonometric ratios, this is probably best done as a classroom exercise. Similarly, P6 could take the form of a written assignment where learners must produce answers to two practical engineering problems involving the sine and cosine rule (for example calculate the phasor sum of two alternating currents and evaluate the resultant and the angle between two forces).

Criterion P7 requires learners to calculate the surface areas and volumes for three different regular solids. This could be achieved through an assignment or perhaps by combining it with other criteria in a short formal test.

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

For P9, learners must provide evidence that they are able to determine and then explain the relevance of the mean, median and mode for a set of discrete and grouped data (for example time taken to produce components on a machine rounded to the nearest ten seconds and the 100 resistor values or diameters of pins from P8). This could be done by an assignment. P10 may be assessed through a short formal test, with learners being given a list of the standard differential coefficients and integrals to use.

For M1, learners will need to provide evidence that they can solve a pair of simultaneous linear equations in two unknowns (for example equations formed after the application of Kirchhoff's laws, power transmitted for different belt tensions in a mechanical system). This could be extended to D1 by the introduction of a quadratic equation to be solved simultaneously with a linear equation.

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

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

Both the criteria required to achieve D2 could be assessed through a written assignment. Learners need to apply the graphical methods to the solution of two engineering problems involving exponential growth and decay (for example growth of voltage in a capacitor, radioactive decay, application of Taylor's tool life equation $C = VT^n$) and then analyse the results by applying the appropriate method of differential calculus to check the results.

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

Unit 14: Mechanical Principles of Engineering Systems

Level: 3

Unit type: Optional

Assessment type: Internal

Guided learning hours: 60

Unit introduction

The use and application of mechanical systems is an essential part of modern life. The design, manufacture and maintenance of these systems are the concern of engineers and technicians who must be able to apply a blend of practical and theoretical knowledge to ensure that systems work safely and efficiently. Science underpins all aspects of engineering and a sound understanding of its principles is essential for anyone seeking to become an engineer.

In this unit, you will be introduced to the behaviour of loaded engineering materials and the analysis of a range of static engineering systems. You will gain an understanding of dynamic systems through the application of Newtonian mechanics. Finally, you will deal with the effects of heat transfer, the expansion and compression of gases and the characteristic behaviour of liquids at rest and in motion.

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

Learning outcomes

In this unit you will:

1 Be able to determine the effects of loading in static engineering systems

2 Be able to determine work, power and energy transfer in dynamic engineering systems

3 Be able to determine the parameters of fluid systems

4 Be able to determine the effects of energy transfer in thermodynamic systems.

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Content

What needs to be learned
Learning outcome 1: Be able to determine the effects of loading in static engineering systems
Non-concurrent coplanar force systems: graphical representation, e.g. space and free body diagrams; resolution of forces in perpendicular directions, e.g. $F_x = F\cos\theta$, $F_y = F\sin\theta$; vector addition of forces, resultant, equilibrant, line of action; conditions for static equilibrium ($\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma M = 0$) *Simply supported beams*: conditions for static equilibrium; loading (concentrated loads, uniformly distributed loads, support reactions) *Loaded components*: elastic constants (modulus of elasticity, shear modulus); loading (uniaxial loading, shear loading); effects, e.g. direct stress and strain including dimensional change, shear stress and strain, factor of safety
Learning outcome 2: Be able to determine work, power and energy transfer in dynamic engineering systems
Kinetic parameters: e.g. displacement (s), initial velocity (u), final velocity (v), uniform linear acceleration (a) *Kinetic principles*: equations for linear motion with uniform acceleration $v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$, $s = \frac{1}{2}(u + v)t$ *Dynamics parameters*: e.g. tractive effort, braking force, inertia, frictional resistance, gravitational force, momentum, mechanical work ($W = Fs$), power dissipation (average power = $\frac{W}{t}$, instantaneous power = Fv), gravitational potential energy ($PE = mgh$), kinetic energy ($KE = \frac{1}{2}mv^2$) *Dynamic principles*: Newton's laws of motion, D'Alembert's principle, principle of conservation of momentum, principle of conservation of energy
Learning outcome 3: Be able to determine the parameters of fluid systems
Thrust on a submerged surface: hydrostatic pressure, hydrostatic thrust on an immersed plane surface ($F = \rho gAx$); centre of pressure of a rectangular retaining surface with one edge in the free surface of a liquid *Immersed bodies*: Archimedes' principle; fluid, e.g. liquid, gas; immersion of a body, e.g. fully immersed, partly immersed; determination of density, e.g. using floatation, specific gravity bottle *Flow characteristics of a gradually tapering pipe*: e.g. volume flow rate, mass flow rate, input and output flow velocities, input and output diameters, continuity of volume and mass for incompressible fluid flow

Learning outcome 4: Be able to determine the effects of energy transfer in thermodynamic systems
Heat transfer: heat transfer parameters, e.g. temperature, pressure, mass, linear dimensions, time, specific heat capacity, specific latent heat of fusion, specific latent heat of vaporisation, linear expansivity; phase, e.g. solid, liquid, gas; heat transfer principles, e.g. sensible and latent heat transfer, thermal efficiency and power rating of heat exchangers; linear expansion *Thermodynamic process equations:* process parameters, e.g. absolute temperature, absolute pressure, volume, mass, density; Boyle's law (pV = constant), Charles' law ($\frac{V}{T}$ = constant), general gas equation ($\frac{pV}{T}$ = constant), characteristic gas equation ($pV = mRT$)

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P1 Calculate the magnitude, direction and position of the line of action of the resultant and equilibrant of a non-concurrent coplanar force system containing a minimum of four forces acting in different directions		
P2 Calculate the support reactions of a simply supported beam carrying at least two concentrated loads and a uniformly distributed load		
P3 Calculate the induced direct stress, strain and dimensional change in a component subjected to direct uniaxial loading and the shear stress and strain in a component subjected to shear loading	M1 Calculate the factor of safety in operation for a component subjected to combined direct and shear loading against given failure criteria	
P4 Solve three or more problems that require the application of kinetic and dynamic principles to determine unknown system parameters	M2 Determine the retarding force on a freely falling body when it impacts on a stationary object and is brought to rest without rebound, in a given distance	D1 Compare and contrast the use of D’Alembert’s principle with the principle of conservation of energy to solve an engineering problem

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P5 Calculate the resultant thrust and overturning moment on a vertical rectangular retaining surface with one edge in the free surface of a liquid		
P6 Explain Archimedes' Principle	M3 Determine the upthrust on an immersed body	D2 Evaluate the methods that might be used to determine the density of an irregular shaped solid material.
P7 Use the continuity of volume and mass flow for an incompressible fluid to determine the design characteristics of a gradually tapering pipe		
P8 Calculate the dimensional change when a solid material undergoes a change in temperature and the heat transfer that accompanies a change of temperature and phase	M4 Determine the thermal efficiency of a heat transfer process from given values of flow rate, temperature change and input power	
P9 Solve two or more problems that require application of thermodynamic process equations for a perfect gas to determine the unknown parameters of the problems.	M5 Determine the force induced in a rigidly held component that undergoes a change in temperature.	

Further information for tutors and assessors

Essential resources

As this is a very practical-based unit, centres should provide access to laboratory facilities with a sufficient range of investigation and demonstration equipment wherever possible. In particular, tensile testing equipment, dynamics trolleys, linear expansivity apparatus, apparatus to determine density and apparatus for verification of Boyle's and Charles' laws would be of significant value.

Suggested reading

Textbooks

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

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

Bird J – *Science for Engineering* (Routledge, 2012) ISBN 9780415517881

Darbyshire A – *Mechanical Engineering BTEC National Level 3 Specialist Units* (Routledge, 2010) ISBN 9780080965772

Tooley M and Dingle L – *BTEC National Engineering* (Routledge, 2010) ISBN 9780123822024

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1	Static Systems	Problems involving engineering components subjected to static force systems.	A written report containing an introductory explanation to each step in the sequence of calculations and findings.
P4, M2, D1	Dynamic Systems	Problems involving force, work and power in dynamic engineering system.	A written report containing an introductory explanation to each step in the sequence of calculations and findings.
P5, P6, P7, M3, D2	Fluid Systems	Problems involving hydrostatic thrust and fluid dynamics. Experimental methods used to determine density.	A written report containing an introductory explanation to each step in the sequence of calculations and findings, and an evaluation of the methods used to determine density.
P8, P9, M4, M5	Thermodynamic Systems	Problems involving heat transfer and dimensional change in thermodynamic systems and involving the expansion and compression of gases.	A written report containing an introductory explanation to each step in the sequence of calculations and findings.

Assessment

The criterion P1 requires the solution of a single non-concurrent force system that contains a minimum of four active forces. It will be expected that two of these forces will be set to act in directions other than the horizontal and vertical. This will necessitate the resolution of forces in perpendicular directions, for example the use of $F_x = F\cos\theta$ and $F_y = F\sin\theta$, as the first step in the solution to the problem. A typical problem might be an engineering component under the action of at least four non-concurrent forces whose magnitudes and directions are given. One of the forces might be its own weight but at least two of them should act in directions other than the horizontal and vertical. Learners would be expected to produce space and free body diagrams, resolve forces horizontally and vertically and take moments of the forces about some suitable reference point. The magnitude and direction of the resultant force and the position of its line of action could then be found through vector addition, application of Pythagoras' theorem and consideration of the resultant turning moment.

P2 will use similar skills to those required for P1 but in this case they will be applied to a simply supported beam carrying two point loads, as a minimum, and a uniformly distributed load. These specifications will provide centres with a variety of loading possibilities that can be used for assessment purposes. During the delivery phase for this part of the unit a greater range of loading may be considered but centres need only work with the minimum for assessment purposes. Neither the content nor criteria stipulate that the point loads should be anything other than perpendicular to the beam. During delivery however, it may be useful to demonstrate the resolution of forces applied at an angle to the beam and calculation of the magnitude and directions of the support reactions.

The assessment for criterion P3 will require a task to calculate the direct stress, direct strain and the accompanying dimensional change in a directly loaded component. It will also require a task to calculate the shear stress and shear strain in a component or material subjected to shear loading. Centres should consider how the tasks set for P3 could be extended to incorporate an opportunity to achieve M1. This might involve consideration of the factor of safety in operation for an angled joint that is bolted or riveted such that the fastenings are subjected to both tensile and shearing forces.

It will require the setting of at least three dynamic system tasks to ensure that the range of kinetic and dynamic principles is applied to achieve P4. Centres should not fragment the application of kinetic and dynamic principles to the extent that they over simplify the problems. It is the interrelationships between the kinetic and dynamics principles that are as important as the use of any single equation. The principles applied in P4 can be directly linked to M2, although achievement of M2 will require a further task to be set to consider the impact of a freely falling body. Suitable examples of this type of problem are listed in the delivery section of these guidance notes. A final task to achieve the distinction criterion D1 will be required to enable learners to consider and solve an engineering problem using the two alternative approaches (i.e. D'Alembert's principle and the principle of conservation of energy), and compare the two methods.

P5 may be achieved by calculating resultant thrust and overturning moment on a rectangular retaining surface, examples of which are listed in the delivery section. P6 requires an explanation of Archimedes' Principle.

M3 may be achieved by calculating the upthrust on a totally immersed body using Archimedes' principle. An understanding of fluid principles is needed to achieve D2, which requires learners to evaluate the methods used to determine the density of an irregular shaped solid object.

The criterion P7 examines learners' basic understanding of fluid flow. It may be achieved by considering the design of a gradually tapering pipe to suit given dimensional and flow constraints.

The criteria P8 and P9 have been designed to assess the thermodynamics aspects of the unit. P8 will require tasks to determine the dimensional change in an engineering component that accompanying a change in temperature, and the sensible and latent heat transfer that accompanies a change of temperature and phase in a substance. P9 will require tasks involving the range of thermodynamic process equations applicable to the expansion and compression of an ideal gas. The area of work covered by P8 – the effects of heat transfer – is extended in the merit criteria M4 and M5.

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Unit 15: Computer-aided Drafting in Engineering

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

Unit introduction

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

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

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

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

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

Learning outcomes

In this unit you will:

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

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

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

4 Be able to produce and interpret CAD drawings

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

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Content

What needs to be learned
Learning outcome 1: Know the national and international standards and conventions that CAD drawings and design need to comply with
Requirements of current national and international standards and conventions: engineering drawing practice: BS 8888:2013, BS 5070-3 1988, BS EN 13622:2002, ISO standards *Features of CAD drawings that need to comply with national and international standards*: drawing sheet sizes and layouts, projection – first and third angle types of line, lettering and numbering, dimensioning, section cross hatching *Standard representations*: welding symbols, electrical symbols, pneumatic/hydraulic symbols, mechanical symbols
Learning outcome 2: Know the advantages of using CAD in comparison with other methods
Advantages of CAD: quality; accuracy; time; cost; electronic transfer of information; links with other software, e.g. CAD/CAM, rendering software, animation software, finite element analysis (FEA) *Other methods:* manual drafting; model making
Learning outcome 3: Know about the software and hardware required to produce CAD drawings
Software: operating systems; CAD software packages, e.g. AutoCAD, AutoCAD/Inventor, Microstation, Catia, Pro/ENGINEER, Solidworks; minimum system requirements, e.g. hard disk space, memory required, processor, video card *Hardware*: keyboard; mouse; other input devices, e.g. light pen, digitiser, joystick, thumbwheel; monitor; printer; other output devices, e.g. plotter, rapid prototyping; storage, e.g. floppy disk, hard disk, memory stick, CD, network
Learning outcome 4: Be able to produce and interpret CAD drawings
CAD drawings: orthographic projections; circuit diagrams, e.g. hydraulic, pneumatic, electronic; exploded/ assembly drawing; standards, e.g. BS 8888, BS 3939, BS 2917 *Commands*: absolute/relative/polar coordinates; features, e.g. linetypes, grids, snaps, circle, text, hatching, dimensioning, layers/levels, colour; viewing, e.g. zoom, pan; inserting other drawings, e.g. symbols, blocks; modifying, e.g. copy, rotate, move, erase, scale, chamfer, fillet *Interpret*: determine properties of drawn objects, e.g. list, distance, area, volume
Learning outcome 5: Be able to use CAD software to produce 3D drawings and views
3D environment: 3D views, e.g. top, front, side, isometric *3D models*: 3D techniques, e.g. addition and subtraction of material, extrude, revolve, sweep, 3D coordinate entry (x, y, z), wire frame drawing, 2D to 3D (thickness, extrusion); surface models; solid models

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P1 Describe the requirements of national and international standards and conventions relating to engineering drawing practice		
P2 Explain which features of CAD drawings need to comply with national and international standards		
P3 Explain the advantages, compared to other methods, of producing drawings electronically using a CAD package	M1 Explain the relationship between CAD and other software/hardware used in manufacturing	D1 Justify the use of CAD in a manufacturing company
P4 Describe the software and hardware that are required to produce CAD drawings		

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P5 Produce 2D CAD detail drawings of five components that make up an assembly or sub-assembly to given standards, using appropriate commands	M2 Explain how the range of commands used to produce CAD drawings can impact drawing production	
P6 Produce a circuit diagram containing at least five components to appropriate standards, using appropriate commands		
P7 Produce an assembly drawing and exploded view of an assembly or sub-assembly containing at least five parts, using appropriate commands		
P8 Interpret the properties of an engineering component or circuit from a given CAD drawing		
P9 Construct a 3D CAD drawing as a surface and solid model.	M3 Explain how 3D CAD models can be used in the design process.	D2 Evaluate the impact of the use of 2D and 3D CAD models on final design requirements.

Further information for tutors and assessors

Essential resources

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

Suggested reading

Textbooks

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

Cheng R – *Using Pro/Desktop 8* (Delmar, 2004) ISBN 9781401860240

Conforti F – *Inside Microstation* (Delmar, 2005) ISBN 9781418020842

Simmons C, Maguire D and Phelps N – *Manual of Engineering Drawing* (Butterworth-Heinemann, 2009) ISBN 9780750689854

Yarwood A – *Introduction to AutoCAD 2012* (Routledge, 2011) ISBN 9780080969473

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Criteria covered	Assignment title	Scenario	Assessment method
P1 and P2	National and International Standards Report	Learners to research national and international standards and relate to engineering CAD drawing practice.	A report describing national and international standards and an explanation of CAD features that need to comply with these standards.
P3, P4, M1 and D1	CAD Report	Learners to research and compare the use of CAD with other methods and determine the software and hardware required to produce CAD drawings; in addition an investigation of how CAD links to other software and hardware and a justification of the use of CAD in manufacturing.	A report containing written responses about the use of CAD and alternative methods; in addition the software and hardware requirements of a CAD system should be listed and explained. An explanation of how CAD links with other software and hardware should support a justification of the use of CAD in a manufacturing context.

Criteria covered	Assignment title	Scenario	Assessment method
P5, P7 and M2	CAD Portfolio	Learners to create an assembly drawing of at least five parts and detail CAD drawings of the five components; in completing the task learners should be able to explain how they used a range of commands in the CAD software to efficiently produce drawings.	A portfolio of five component drawings and an assembly drawing containing the five individual parts; in addition a short report containing written responses and/or screen dumps explaining how a range of CAD commands were used to efficiently produce the completed drawings.

Assessment

An assignment could cover P1 and P2 and should be structured so that learners remain focused on the content of learning outcome 1. Learners are expected to use their own words when referring to the national and international standards and conventions. While much of their research will be done using the internet, it is important that what they present is not just a simple cut and paste exercise. Evidence to support knowledge of which features of CAD drawings comply with national and international conventions could be generated by giving learners drawings which highlight the details required for meeting National and International conventions.

The assessment evidence for P3 and P4 could be produced through a case study or through studying the company in which learners may be employed. Typically, it would take the form of a written report or presentation. To achieve P3, learners must demonstrate an understanding of how CAD is used in comparison with more traditional drawing methods, stating its advantages and explaining how CAD systems can be linked with other software. A description of basic hardware and software requirements to operate a CAD system will be required to achieve P4.

The remaining pass criteria could be evidenced through a series of competence-based practical activities. Evidence could be in the form of witness statements, tutor observation records or a portfolio, although it is likely that electronic files will be used for the majority of the assessment. Screen dumps can often be a good source of evidence to show the range of commands used during the development of the drawings. The process evidence for these remaining pass criteria (P5 to P9) could be obtained from further assignments. In the first of these, learners would be required to produce five separate CAD drawings of the components which make up an assembly or sub-assembly. The full range of commands must be used and the drawings should be dimensioned to an appropriate standard, enabling P5 to be achieved. These drawings could then be used to produce an assembly and exploded view drawing (P7).

A further assignment would require production of a circuit diagram to achieve P6. This might reflect learners' occupation or area of interest and should be assembled from symbols previously introduced by the tutor and/or externally sourced. This assignment could also ask learners to interpret and provide a summary of the information contained in a given detail drawing or circuit diagram (P8).

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

To achieve a merit grade, learners will need to look beyond how drawings are produced and evaluate their use and application. This will typically be through looking more closely at the relationship between CAD and other software. Learners should explain how linking CAD to other software/hardware impacts on an organisation (for example improving production, reducing waste, reducing lead times). This will build on the evidence generated for P3 and enable the M1 merit criterion to be achieved.

An explanation of the range of commands for criterion M2 and how they impact on drawing production in terms of efficiency (for example speed, accuracy, repeatability) links with P5, P6 and P7. Similarly, knowledge for the M3 criterion of how 3D models can be used in the design process links with the 3D activity in P9.

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

To achieve the D2 criterion learners will need to evaluate 2D and 3D drawings from a customer perspective. This links directly with the P9 and M3 criteria. Learners will need to compare and contrast the impact on customers of producing drawings using 2D and 3D CAD and how customers might use the information produced.

Unit 16: Applications of Computer Numerical Control in Engineering

Level: 3

Unit type: Optional

Assessment type: Internal

Guided learning hours: 60

Unit introduction

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

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

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

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

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

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

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

Learning outcomes

In this unit you will:

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

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

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

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

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Content

What needs to be learned
Learning outcome 1: Understand the principles of computer numerical control (CNC) and machine structures
CNC principles: system, e.g. machine control unit, drive mechanisms, tool/workpiece interface, transducers, feedback, correction; datum points, e.g. machine, component; definition of parameters using numerical coding, e.g. position, movement, spindle speeds, cutting tools, clamping, application of coolant; CNC process, e.g. select machine, select tooling, identify machining sequence, calculate positional coordinates, calculate spindle speeds, programming, post-processing, setup sheet, verify and edit, store for future use *Machine structures*: types, e.g. milling, drilling, turning centre, machining centre; designation of axes, e.g. 2 axis, 3 axis, x, y, z; motor and drive units, e.g. spindles, stepless drives, ball screw, stepper motors; transducers, e.g. positional, linear, rotary, analogue, digital, optical encoders, inductive, capacitive, magnetic; tooling e.g. modular, quick change, turret; tool transfer e.g. automatic, chain magazine, circular magazine; work holding, e.g. pallets, sub tables, rotary work changer, grid plate; swarf removal, e.g. chutes, chip controllers, conveyors; cooling, e.g. cutting fluid, cooling systems; computer hardware, e.g. keypad, display, Central Processing Unit (CPU), storage, cabling links, machine control unit (MCU); computer software, e.g. programming language, CAD/CAM DXF files; safety, e.g. overloading the cutting tool, guards, light barriers, interlocks, operator safety
Learning outcome 2: Be able to interpret a component specification and produce an operational plan for its manufacture
Component specification: detailed drawing; material, e.g. steel, aluminium, polymer, other stable material; reference points, e.g. edge datum, centre line datum; dimensional, e.g. external, internal, centres distances, bore diameters, tolerances; surface finish, e.g. R_a, R_z values *Operational plan*: zero datums; work holding, e.g. clamps, fixtures, chucks, vices, setting points; changing components, e.g. pallets, sub tables, rotary work changer, grid plate; sequence of operations, e.g. loading, machining, roughing and finishing operations, measurement, unloading; calculations, e.g. cutter path coordinates for intersections, polar centres, arc centres, cutter compensation, cutting speeds, feed rates; use of trigonometric ratios, e.g. sine, cosine, tangent; cutter speed ($\frac{\text{surface speed}}{\pi} \times$ cutter diameter); feed rate (feed per tooth × number of teeth × spindle speed); grouping of similar operations; canned cycles, e.g. irregular pockets, geometric, hole patterns; tooling, e.g. cutters, drills, reamers; other reference data, e.g. cutting fluids, special requirements relating to specific materials; inspection, e.g. first off proving against specification, on machine measurement; set up sheet and tool list

Learning outcome 3: Be able to produce a part program and manufacture a component
Part program: user interface, e.g. menu bar, identification line, tool display window, system status; work/tool relationships, e.g. position, direction, amount of movement; rates of change, e.g. feed rates, spindle speeds; auxiliary functions, e.g. metric/imperial units, tool selection, cutting fluids, workpiece loading and holding, tool changing; CNC codes e.g. block number, preparatory functions (G codes); miscellaneous functions (M codes); other letter addresses (arc centres, spindle speed, feed rate); dimensional information, e.g. axis coordinates (x, y, z), absolute, incremental; words, e.g. modal, non-modal; block format, e.g. block number, G code, coordinates; special function G codes, e.g. movement system, measuring system, tool compensation, canned cycles, subroutines; M codes, e.g. coolant, tool change, work holding, spindle speed, spindle direction *Manufacture:* post-processing, e.g. transfer of files/data between systems, download program to machine tool; pre-manufacture, e.g. run through using graphics display on machine tool, prove program, dry run, load workpiece, stepping, adjust feed rates; run program, e.g. machine workpiece, first off inspect and check against specification, store verified program for future use, quality monitor; shutdown
Learning outcome 4: Be able to use a CAD/CAM software package to generate a part program and manufacture a component
CAD/CAM package: hardware, e.g. CAD workstation, data storage, hard copy equipment, network system to download data to machine tools; software, e.g. Autodesk Inventor, Esprit, Solid Works, Edge CAM, Denford VR milling/turning; universal formats, e.g. extensions (such as DXF, IGS, AI, EPS, PLT, NC), proprietary formats (such as DWG, CDR, CDL, GE3, NC1, BMP, MSP, PCX, TIF) *Part program*: e.g. 3D geometric model using CAD software, select machining operations, select tooling, generate CNC program using CAM software, simulation of tool changing and tool paths in the machining process, correction and editing *Manufacture*: post-processing, e.g. transfer of files/data between systems, download program to machine tool; manufacturing, e.g. load and clamp workpiece, set tooling, initiate program cycle, machine workpiece, first off inspect and check against specification, store verified program for future use, quality monitor; shutdown

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P1 Describe the principles on which a machine tool operates when controlled by a CNC system		
P2 Describe, with the aid of suitable diagrams, the structure of a given CNC machine type		
P3 Interpret the specification for a given component and produce an operational plan for its manufacture	M1 Explain the importance of producing an accurate and detailed operational plan for a component that is to be manufactured using a CNC machine tool	
P4 Produce a part program for a given component	M2 Explain the importance of correct programming and setting up in order to produce a component to a required specification.	
P5 Manufacture a component using a two- or three-axis CNC machine		
P6 Use a CAD/CAM package to produce a part program from a given component detail drawing	M3 Test the program explaining how it meets the requirements of the drawing	D1 Compare and contrast the effectiveness of a CAD/CAM method of manufacturing a component to that of using CNC part programming

Assessment criteria		
Pass To achieve a Pass grade the evidence must show that the learner is able to:	**Merit** To achieve a Merit grade the evidence must show that, in addition to the Pass criteria, the learner is able to:	**Distinction** To achieve a Distinction grade the evidence must show that, in addition to the Pass and Merit criteria, the learner is able to:
P7 Manufacture a component on a CNC machine using a post-processed program generated using CAM software.	M4 Explain how the manufactured component meets the requirements of the program.	D2 Evaluate the cost benefits of using CAD/CAM software when programming CNC machines.

Further information for tutors and assessors

Essential resources

In order to deliver this unit, centres will need to have 2D/3D commercial CAD software and CAM software that integrates with the CAD package used for designing. They will also need to have access to a two- or three-axis CNC machine tool and a two- or three-axis machine tool which can be downloaded with data from a computer system.

Suggested reading

Textbooks

Evans K – *Programming of CNC Machines* (Industrial Press, 2007)
ISBN 9780831133160

Smid P – *CNC Programming Handbook* (Industrial Press, 2008)
ISBN 9780831133474

Timings R L – *Basic Manufacturing* (Routledge, 2004) ISBN 9780750659901

Essential information for assessment

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

Please read this guidance in conjunction with *Section 8 Assessment*.

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2	CNC Principles and Machines	An assignment that requires learners to demonstrate their knowledge of the underlying principles of CNC machines and CNC machine structures.	Two written tasks for which learners need to produce an explanation of the principles on which machine tools operate, and a written description of CNC machine structure.
P3, M1	Component Specifications and Operational Plans for Manufacture	A practical assignment that requires learners to interpret a component specification and produce a plan for its manufacture.	A practical task for which learners are given a detailed drawing and information on a component that they need to interpret. Learners produce an operational plan to manufacture the product on a CNC machine. A further written task gives learners an opportunity to explain the importance of an accurate and detailed plan.

Criteria covered	Assignment title	Scenario	Assessment method
P4, P5, M2	Part Programs for Manufacturing Components	A practical assignment that requires learners to produce a part program and use it to manufacture a component.	Practical tasks in which learners are given a pre-produced operational plan for which they produce a part program and manufacture a component using three-axis machining.
P6, P7, M3, M4, D1, D2	Using CAD/CAM to Manufacture Components	A practical assignment, supported by written tasks, that requires learners to demonstrate their ability to use CAD/CAM to manufacture a component.	Practical and written tasks. Learners are given a detailed drawing for which they write a part program. Learners then need to use their post-processed program to manufacture the component. Written tasks will ask learners to compare CAD/CAM to CNC part-programming and evaluate the cost benefits of CAD/CAM.

Assessment

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

It is suggested that the first assignment covers grading criteria P1 and P2, with learners being asked to produce a written report. Evidence for P1 should be generic and not specific to a particular type of machine. There is a lot of material that learners will have access to and care should be taken to ensure the validity of the evidence they provide.

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

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

Further evidence in the form of annotated drawings and specification sheets, calculations to support machining decisions such as speeds and feeds and trigonometric ratios to calculate coordinates and intersections will also be needed to support P3. Evidence presented for M1 should make reference to the operational plan produced for P3 but additional evidence drawn from wider sources should be included.

The third assignment could be designed around P4, P5 and M2. It will add realism if the same component is used for both pass criteria. Learners should be given a pre-produced operational plan to work from, although if they wish they could use the one produced for P3, providing it is fit for purpose. The only requirement is that the part program and manufacturing relate to a single component which is significantly more complex that the one looked at in *Unit 31: Computer-aided Manufacturing*. Three-axis machining would be the preferred option, using something like a vertical milling machine. As the assignment involves a lot of practical work, evidence presented for assessment should include screenshots, witness statements, observation records and annotated digital images.

The fourth assignment could cover P6, P7, M3, M4, D1 and D2. Learners who wish to gather evidence for D1 will probably want to use the component specification provided in the third assignment so that they can contrast the effectiveness of the two methods of programming. The starting point for P6 is a detailed drawing and this should be given to learners as a file which can be opened using CAD/CAM software. With the agreement of the tutor, some learners who are taking the CAD unit may wish to use a component that they have previously drawn, but it needs to be in a form that can be easily processed.

Evidence presented for assessment should include screenshots showing tool path simulation, witness statements, observation records and annotated digital images. A written task will need to be given asking learners to compare and contrast the effectiveness of a CAD/CAM method of manufacturing a component to that of using CNC part programming (D2). They will obviously need to identify benefits and limitations of each approach and draw valid supported conclusions. The focus of D1 is very specific and some of the evidence presented could relate to the tasks undertaken to achieve P4, P5, P6 and P7. M3 and M4 are logical extensions of P6 and P7 respectively requiring explanations of how the entities produced meet the original requirements.

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

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

Some of the evidence for D2 could be come from work produced for *Unit 31: Computer-aided Manufacturing* and it may be possible to integrate assignments across units. Because there are well documented examples of the cost benefits achieved by companies who use CAD/CAM software to program CNC machines, care must be taken to ensure that what the learner presents as evidence is authentic. Use could be made of experience from *Unit 44: Setting and Proving Secondary Processing Machines*, particularly about work holding and machining parameters. Where appropriate, employed learners should be given the option of using examples taken from their own company.

13 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:

- *Adjustments for candidates with disabilities and learning difficulties – Access Arrangements and Reasonable Adjustments, General and Vocational qualifications* (Joint Council for Qualifications (JCQ))
- *Equality Policy* (Pearson)
- *Recognition of prior learning policy and process* (Pearson)
- *UK Information Manual* (Pearson)
- *UK BTEC Quality Assurance Handbook* (Pearson).

All of these publications are available on our website.

Publications on the quality assurance of BTEC qualifications are also available on our website.

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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.

14 Professional development and training

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- building your team and teamwork skills
- developing learner-centred learning and teaching approaches
- building in effective and efficient quality-assurance systems.

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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 qualifications.pearson.com/en/support/contact-us.html

Annexe A

Qualification mapping to the Composites Engineering Apprenticeship Standard

Unit number	Mandatory units	Mapped to QCF unit	Full or partial mapping
1	Health and Safety in the Engineering Workplace	1	Full
2	Engineering Drawing for Technicians	16	Full
3	Principles of Working Effectively and Efficiently within Composites Engineering	N/A	
4	Business Improvement Techniques	42	Partial
5	Composite Materials	N/A	
6	Composites Manufacturing Processes	N/A	
7	Composites Engineering Product Design and Manufacture	N/A	
8	Defects, Detection and Repair Processes in Composites Mouldings	N/A	
9	Composites Engineering Project	3	Partial
Unit number	**Optional units**	**Mapped to QCF unit**	**Full or partial mapping**
10	Making Composite Parts Using Prepreg Materials	N/A	
11	Wet Layup Techniques	N/A	
12	Making Composite Parts Using Resin Infusion Techniques (VRTM & RTM)	N/A	
13	Mathematics for Engineering Technicians	4	Full
14	Mechanical Principles of Engineering Systems	5	Full
15	Computer-aided Drafting in Engineering	17	Full
16	Applications of Computer Numerical Control in Engineering	26	Full

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